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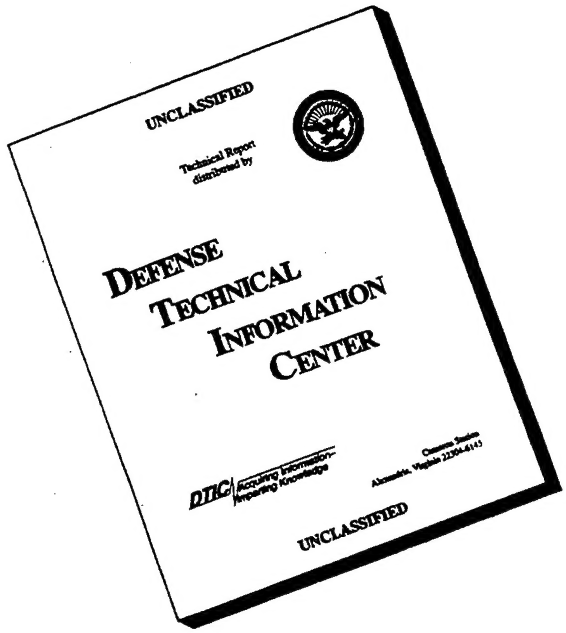

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-- 1 - AD NUMBER: D428595
-- 5 - CORPORATE AUTHOR: SOCIETY OF PLASTICS ENGINEERS GREENWICH CONN*
-- 6 - UNCLASSIFIED TITLE:     PROCESSING AND FINISHING OF PLASTICS IN
--     SMALL BUSINESS EQUIPMENT AND MACHINE PARTS.
--11 - REPORT DATE:        SEP 20, 1979
--12 - PAGINATION:     120P
--20 - REPORT CLASSIFICATION:  UNCLASSIFIED
--21 - SUPPLEMENTARY NOTE:     PROCEEDINGS: REGIONAL TECHNICAL CONFERENCE,
--     'PROCESSING AND FINISHING OF PLASTICS IN SMALL BUSINESS EQUIPMENT
--     AND MACHINE PARTS', 20 SEP 79, ROCHESTER N.Y. SPONSORED BY SOCIETY
--     OF PLASTICS ENGINERS, ROCHESTER SECTION. (SEE PL-33724 - PL-33727).
--22 - LIMITATIONS (ALPHA):    APPROVED FOR PUBLIC RELEASE; DISTRIBUTION
--     UNLIMITED. AVAILABILITY: SOCIETY OF PLASTICS ENGINEERS, 656 WEST
--     PUTNAM AVE., GREENWICH, CT. 06830.
--33 - LIMITATION CODES:  1  24
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428599

PROCESSING AND FINISHING OF PLASTICS

IN

SMALL BUSINESS EQUIPMENT AND MACHINE PARTS

Regional Technical Conference
Sponsored by
Rochester Section
Society of Plastics Engineers, Inc.
September 20, 1979

"PROCESSING AND FINISHING OF PLASTICS

IN

SMALL BUSINESS EQUIPMENT AND MACHINE PARTS"

Regional Technical Conference
Sponsored by
ROCHESTER SECTION
Rochester, New York
September 20, 1979

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The Outlook for Plastics in Business Machines

by D. V. Rosato

This review will show that business equipment will continue to be an important customer for the plastics industry. Estimates on past, present and future plastic consumption will be provided. The estimates will also provide input on product applications, types of plastics, and plastic processes used. A listing of companies that produce these machines using plastics show their interest and also provide an indication on future trends. They represent true innovators who have adopted plastics. A prognosis for the industry will be included.

The growth in the use of plastics in business machines has been quite spectacular. Its yearly rate has averaged about 12%. Present consumption is estimated at 620 million pounds this year. (Appliance Manufacturer).
Future growth rate predictions range from 6 to 15% annually based on forecasts from various sectors of the industry. Since business machine growth rate is expected to be in the double digit (to move our enormous USA and worldwide business communication system) one could estimate at least 8 to 10%. Enclosure 1 provides input on their past, present and future forecast regarding shipments of the different machines.

Types of Plastics

The plastics being used are rather extensive. A rough estimate of the amount consumed percentage wise, is as follows: ABS at 25%, high impact polystyrene at 20%, polypropylene at 12%, polyvinyl chloride at 7%, polyurethane at 7%, PPO at 4%, polycarbonate at 4%, nylon at 2%, SAN at 2%, acrylic at 1%, acetal at 1%, polysulfone at 1/2% and others

Consumption by process is estimated percentage wise at 52% for injection molding, 23% for extrusion, 9% for compression, 8% for coating, and 8% for others.

Business machines and other appliances are the fastest growing outlet for RP, registering a 130% increase between 1969 and 1978. (Reinforced plastics)

Business machines is one of the smaller consuming areas of engineering thermoplastics but it is estimated that their growth rate will be at 20% per year. These plastics include nylons, polycarbonate, fluroplastics, polyaryl ether, polyimide, and polysulfone.

Business machines is one of seven basic categories in overall diversified industry of appliances. Enclosure 2 explains these categories and also lists the business machines.

Performance

For the unfamiliar (to the use and properties of plastics), plastics have almost unlimited versatility for styling and molded-in details, they are lightweight, chemical resistant and have many other good properties.

Plastic materials and process technologies offer many opportunities. The key is to capitalize on them more effectively. In the past, since there was a choice of attractive plastic materials, it was not difficult to obtain significant cost advantages in substitution of other materials. The challenge is different now since competition between the materials is on the increase, particularly plastics to plastics.

Plastics are relatively low cost, large volume materials comparable to metals. The phenomenal widespread use and rapid growth result largely from their versatile properties covering all ranges of requirements such as soft or flexible to rigid or extremely high stiffness that can be produced in small to large quantities integrally colored, non-corroding, with low to high cost/ performance. Most plastics are used because of desirable properties at an economical cost.

Regrettably generally no one plastic meets all your requirements; therefore, it is important to understand and obtain the basis on the availabiltiy and applicable processing techniques of all plastics. No one material (plastics, metals, ceramics, etc) has the perfect profile for all applications in as much as performance requirements differ. Each has a niche. Insights into the principles of selection will enable thoughtful users to select the best material for each purpose thus avoiding materials which might be inadequate in certain respects or extravagant.

As these advantages became more widely recognized and exploited properly, business machines are to be a key market for plastics.

What is Ahead

Bright or cloudy, there is little question that the future of plastics will be shaped by factors that are different from the influences of the past. There are those who say that the cream has been skimmed and that the day of the easy, quick-payoff application for plastics is over. These observers maintain that considerably higher levels of technology and capital investment will be needed if plastics are to continue to grow at their past rate.

They contend that consumer pressures for higher reliability and the problems of safety and energy consumption create new demands, not all of which can be easily satisfied.

Others, while acknowledging the difficulties, maintain that big opportunities still exist, provided the more recent advances in plastic materials and processing procedures as well as the new technology can be applied or developed to meet the requirements.

In the past plastics made significant penetration into all products, including business machines. Continuing price reductions led to relatively easy, direct subsititution of other materials by plastics. It was not difficult to obtain significant cost advantage by making

substitutions since there were many attractive plastics materials. The picture is different now. Plastics prices are rising along with most other competitive materials. Even though they will tend to retain basic cost advantages, the challenge continues to be creating new design concepts and new material/process technologies that will lead to lower overall systems costs and to products that will give higher value in the marketplace.

Inherent Advantages

Plastics have an inherent advantage in requiring less process energy than most other materials. And at the consumer end, because of our national energy situation and all of its ramifications, improved thermal insulation will provide an attractive market potential. They provide a potential for more vertical integration, such as blending and coloring. A lot more can be accomplished in this area. For example, for high volume users, tailored plastics are very attractive to meet specific application needs. More in-house compounding is a promising route to developing more efficient material systems. This approach permits upgrading commodity resins by the use of fillers, reinforcement and new blending techniques.

Arena of Innovative Design

With consumerism interest on the rise, the level of expectations on the performance and quality of products that people buy is on the "usual" increase. However, consumerism may well be an opportunity. To improve profits it will be important to introduce visible product innovation and in general to increase the desirability of products for the customer.

Quality superiority is an important element of desirability to the consumer. To the public the consumer businesses are the stewards

of the company image.
Due to government regulations and our "paper-pushing' world, various forces strongly influence machine design. They include energy shortage, noise abatement, operational safety, and simplicity of "repeated" operation.
All these types of actions require more in-depth analysis of producing the next generation of machines. They may be produced at a very fast rate requiring more innovative design with plastics.

Rapid pace of change

Not exclusive but very significant to the world of business machines, is the rapid introduction of new models tied in with the changing technology used in these machines such as size of computers, more miniaturization in solid state electronic devices, and simplification of mechanical/ motion devices.
As an example, copier manufacturers are turning out new models faster than ever. All types of options exist. And at the same time the low-volume markets are the producers main targets.
Result is more stringent conditions on the use of plastics.

Cost/performance opportunities

A major area where plastics continues to be expanding its use (at 15 to 20% annual growth) is in business machine housewares replacing sheet metal and die castings. In comparison metal fabrication and assembly is rather high, but more significant are the design options that are gained.
As those in the business know, plastic bosses, inserts, integrated structures or supports, and other features can be incorporated during molding to provide major cost/performance gains.
These complex housings can be compression molded using glass fiber-polyester resin sheet molding or bulk molding compounds, injection molded polycarbonate/polystyrene/other resins, reaction injection molded polyurethanes, structural foam molding of polycarbonate/PRO?ABS/PS/other resins,and other material/

process combinations. The processing costs incurred in the various stages of manufacturing a product, much more than the initial raw material cost, form the initial basis of selection of the materials and processes.

The selection of the best process/material combination is influenced by various factors with cost as the major influence. Hand-in-hand go the factors of quantity to be produced (and its rate of production), tooling delivery, pre-production to production scheduling time table, and of couse, meeting product performance requirements (assuming all performance requirements are known and specified). Also add the important factor of competence: competence in setting up performance requirements, part design, mold performance, molders performance, surface finish, and a few others.

Plastics gain

To offset the increasing costs of all machines, leading manufacturers are taking advantage of the cost/performance opportunities with plastics. Although performance is the key materials selection factor in design, rising prices are leading designers to part with traditional materials in favor of more cost effective ones to keep product costs in line.

These manufacturers are not only concerned by the increasing cost of materials, but also, and possibly more so, the escalating costs of energy forms used in parts production and the cost of meeting government ecology regulations. The increasing use of plastics relates largely to cost savings such as low density and its effect on low cost, light weight energy efficiency and ease of handling as well as corrosion and chemical resistance which obviates the need for postfinishing. Also add electrical, thermal and acoustical insulation, integral color in as-molded or as-formed parts ease of molding complex shapes and the ability to mold several parts in single molds.

The result of this type of analysis show that rising costs for traditional materials, as well as gains in technology, makes plastics look better and better.

Embossed steel is of more interest. It is capturing and increasing percentage of the appliance market. Since Whirlpool introduced this "touch and feel" steel on refrigerator doors, the concept has grown to where most appliance manufacturers use it.

It hides finger prints and scratches, offers contemporary appearance, and is easier to keep clean. Embossing is performed by passing plastic coated steel coiled stock through a set of engraving rolls.

Much progress has been made in the use of reinforcing fibers and fillers with more action to occur on what future accomplishments will be made. To date the area of composites in the sense of layered composites has received only limited attention. However action in this technology is on the increase since the concept is to use the minimum amount of material in the right place for its contribution.

Also important to the designer are multi-layer extrusion film/sheet to provide combinations of properties, also multi-component injection molding, such as combining hard and soft vinyls and multi-layer blow molding such as that being used in plastic bottles and containers.

Future

The future of plastics in business machines, like in the other markets where its products are in demand, and with growth on the horizon, will continue to be its major asset. Plastics growth is through technological innovation. So the target is to keep up to date on past, present and new technology coming aboard that exist regarding materials and processes.

A major stumbling block is to effectively transfer to you the wealth of technology that exists in so many areas.

Encl. 1.: Estimated past, present and forecast of shipments for business/office appliances (millions of dollars)

	1977	1978	1979
Adding Machines	40.0	42.0	39.0
Business Computers	2,830.0	3,700.0	4,250.0
Cash Handling Equipment	25.0	26.0	29.0
Check Handling Equipment	57.0	60.0	61.0
Computer Peripherals	4,931.0	5,600.0	6,150.0
Dictating Machines	230.0	215.0	218.0
Duplicating Machines	132.0	141.0	140.0
Form Handling Machines	20.0	22.0	23.0
Letter Handling/Collating Machines	213.0	228.0	232.0
Photocopying/Microfilm Equipment	3,294.0	3,500.0	3,970.0
Typewriters	812.0	869.0	905.0
All Others	161.0	172.0	180.0
TOTAL	12,718.0	14,675.0	16,197.0

Historical data sources: Air-conditioning and Refrigeration Institute: Appliance Manufacturer; Association of Home Appliance Manufacturers; Electronics Industries Association; Foodservice Equipment Specialist Magazine; Gas Appliance Manufacturers Association; Institutions/VF Magazine; Music Operators of America; National Automatic Laundry and Cleaning Council; National Automatic Merchandisers Association; Playmeter Magazine; U.S. Department of Commerce; Bureau of the Census; Vacuum Cleaners Manufacturers Association; Water Quality Association; industry sources.

Enclosure 2: Listing of appliances

BUSINESS OR OFFICE APPLIANCES
Accounts-handling devices (accounting or bookkeeping machines, checkwriters), electromechanical calculators or adding machines, electronic calculators, cash registers, communications systems (facsimile printers, intercoms, retail data terminals, telephone accessories), computers or peripheral devices, copying machines, dictating machines, duplicating machines, general office machines (erasers, pencil sharpeners, punches, staplers), mail processing machines (addressers, cancellers, inserters, label printer/applicators, letter openers, postage meters), microfiche/microfilm equipment, paper-handling machines (automatic files, binders, bursters, collators, cutters, folders, shredders, sorters, stackers), typewriters, and automatic typewriters/word processors.

COMMERCIAL, INSTITUTIONAL OR LABORATORY APPLIANCES
Dental lab amalgamators, lab autoclaves/sterilizers, barber or beauty products, lab centrifuges, trash compactors, cookware, beverage coolers and dispensers, drinking water coolers, dishwashers, food waste disposers, floor polishers/scrubbers and rug shampooers and vacuum cleaners, food preparation products, dental lab furnaces, general purpose lab furnaces, garment-finishing products, mechanical lab glassware washers, ultrasonic lab glassware washers, lab hot plates, lab hot plates/magnetic stirrers, ice makers/dispensers/storage bins, incinerators, general purpose lab incubators, dental lab oral irrigators, electronic ovens, general purpose lab ovens, phonographs and recorders and tape players, electric ranges and ovens, gas-fired ranges and ovens, refrigeration/freezing equipment, blood storage refrigerators/freezers, general purpose lab refrigerators/freezers, sewing/cutting machines, general purpose lab shakers, and lab ultrasonic cleaners.

VENDING OR COIN-OPERATED APPLIANCES
Coin-operated car washers, coin-operated clothes dryers, coin-operated clothes washers, coin-operated drycleaners, money changers, coin-operated/commercial phonographs, beverage vending machines, food vending machines, and packaged merchandise vending machines.

MAJOR HOUSEHOLD APPLIANCES
Electric clothes dryers, gas-fired clothes dryers, clothes washers, trash compactors, dishwashers, food waste disposers, freezers, electric or gas-fired incinerators, combination kitchen units, electronic ovens, range hoods, electric ranges and ovens, gas-fired ranges and ovens, LP gas-fired ranges and ovens, refrigerators and refrigerator/freezers, compact refrigerators and refrigerator/freezers, central vacuum cleaners, electric water heaters, and gas-fired water heaters.

ELECTRIC OR GAS-FIRED HOUSEWARES
Animal clippers, aquarium air pumps, blankets, blenders, can openers/can opener combinations, clocks, coffee grinders, coffee makers, cookware, dental irrigators, facial saunas, fans, electric fireplaces, gas-fired fireplace logs, floor polishers, food grinders, food mixers, food slicers, food warmers, gardening tools, hair cutters, hair dryers, hair setters, hair stylers, heating pads, ice cream makers, ice crushers, irons, juicers, knives, heated lather dispensers, electric lawn mowers, lighted make-up mirrors, manicure sets, massagers and exercise machines, electric outdoor cookers and accessories, gas-fired outdoor cookers, gas-fired outdoor lights, pencil sharpeners, motion picture projectors, still picture projectors, scissors, sewing machines, shavers, shoe polishers, electric snow movers, decorator telephones, toasters, portable tools, stationary tools, toothbrushes, vacuum cleaners, vaporizers, whirlpool baths, and wrinkle removers.

ENVIRONMENTAL COMFORT APPLIANCES
Electrostatic air cleaners, packaged roof-top air conditioners, room air conditioners, unitary air conditioners, air deodorizers/ionizers, electric boilers, gas or oil-fired boilers, gas conversion burners, dehumidifiers, ventilating exhaust fans, room fan-coil units, electric forced-air furnaces, gas-fired floor furnaces, gas-fired wall furnaces, gas or oil-fired duct furnaces, gas or oil-fired forced-air furnaces, heat pumps, electric baseboard heaters, electric duct heaters, electric room heaters, gas-fired room heaters, gas-fired unvented infrared radiant heaters, gas-fired vented infrared radiant heaters, hydronic baseboard heaters, forced-air duct humidifiers, portable humidifiers, and gas or oil-fired unit heaters.

CONSUMER HOME ELECTRONICS
Antenna rotators, high-fidelity components—loudspeakers, phono turntables/changers/cartridges, radio receivers, stereo headphones, turners/pre-amps/amplifiers—intercommunication systems, organs, phonographs, radio receivers, security devices, audio tape cartridges or cassette recorders/players, audio tape recorders, video tape recorders, telephone devices, and television receivers.

INNOVATIONS IN STRUCTURAL FOAM DESIGN FOR OFFICE AND ELECTRICAL COMMUNICATIONS EQUIPMENT

by

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The increased use of structural foam in the field of office and electrical communications equipment has led to many design concept advances. This paper will explore their origin and possible use in future designs. This discussion begins with the philosophy of design in early materials, with emphasis on the emergence of plastics, engineering plastics, and engineering structural foam as an accepted design medium. Examples of early use of structural foam in the fabrication of business machine housings will be addressed, including today's accepted modes of design. Also discussed will be advanced engineering structural foams, along with the design techniques that will allow the designer to expand his philosophies to meet tomorrow's requirements.

The new concepts possible for tomorrow's designers can be brought into context with a review of techniques used both yesterday and today. Yesterday's designer generated his one product from many sub-assemblies. Today, he designs by combining many functions into fewer parts. The origins of design philosophies are related to materials available, and knowledge of that material's potential function required from the end device. The simplistic design of an Indian tomahawk clearly shows design in its infancy. Three materials were used: stone, wood, and leather. Many operations were then needed to assemble the final product, which yielded one function. Larger end products were also designed in this manner. Early dwellings, such as a log cabin, were nothing more than a large assembly of many parts requiring many individual operations to again yield one main function.

What emerged from these early activities were the craftsmen who had gained expertise with an individual process or material. Woodworkers, gunsmiths, and watchmakers are but a few examples of early specialization. But, instead of advancing design concepts, they merely made specialized products from one material with an exhausting amount of operations with one final end use.

It was Henry Ford who, with automation of his Model T assembly line, used the individual craftsmen with their many materials to produce his final product. Detroit today, although it uses new and different materials, still produces automobiles using individual craftsmen.

When the new craftsman emerged, utilizing a plastic material and process, his addition to the world of design and production was revolutionary. Now with <u>one operation</u>, you could produce <u>one part</u>. Examples of early plastic designs were styrenic tableware, and one of the first plastic parts produced in this country, a phenolic tube holder for RCA Victor. The emergence of engineering materials added one important design tool. One-process operation produces a part having many functions. An example of this is the injection molded LEXAN polycarbonate Rockwell Drill housing, which incorporates component mounting bosses, internal ribbing, and double insulating electrical characteristics. Also, exhibiting multifunctional design is an NCR Corporation injection molded LEXAN 500 polycarbonate internal point-of-sale terminal frame. This frame combines approximately nine fabricated metal parts into one single injection molded unit. Cost savings resulting from integrated designs were now obvious.

The challenge to make larger parts sparked the development of the structural foam process for producing plastic parts. Early materials used in this new process were styrene, high density polyethylene, and general purpose ABS, which were used to make furniture, shutters, large shipping pallets, flower pots, and ash tray or waste paper containers.

The design extensions achieved in the engineering materials injection process were now translated to structural foam. Engineering structural foam allowed the production of larger parts in one operation with many functions molded in. The design possibilities and their cost effectiveness resulted in some very exciting new applications. An excellent example of large parts with multifunctional design is the Kodak film processing tank.

This unit is molded entirely of NORYL, a modified polyphenylene oxide resin structural foam. Its mulitfunctional concept is seen in the illustration. The total part weight is approximately 50 pounds.

Combining die cast and fabricated metal parts into one LEXAN Structural Foam printer frame assembly is another fine example from Decision Data.

From the illustration, it is easy to understand the cost effectiveness of this design philosophy.

Western Electric has also designed with this method. The illustration shows their 515 and Comm Key II electronic back panel.

Molded of NORYL Structural Foam, these units support between 100 and 200 pounds of electronic switching gear over a 20-year life. The 515 panel replaces two metal and two sheet molding compound parts in a truly functional design.

The designer today has learned how to take advantage of the engineering structural foam process. He designs business equipment with aesthetic style outside, and function inside.

The aesthetic achievement of the design of Data Terminal Systems' P.O.S. terminal is only surpassed by the cost effectiveness of the inside functional design. The illustration speaks for itself. The material: NORYL Structural Foam.

Other fine examples are: the TRW P.O.S. terminal molded of NORYL Structural Foam - 30 pounds/unit,

the Graphic Sciences Transceiver - LEXAN and NORYL Structural Foam,

and the Houston Instrument Electrostatic line printer.

This Houston Instrument printer used three different structural foam materials: LEXAN, NORYL, and VALOX, a thermoplastic polyester resin. What is most important in this design is the reasoning behind the different resin selections. The top and end covers were designed in NORYL. They have electrical components and circuitry connected to them (utilization of UL 94 V-0 characteristics). The entire frame to this printer was designed in LEXAN. It is the load-bearing structure which also has all components mounting systems molded in, plus more electrical circuitry attached (utilization of higher modulus and UL 94 V-0 characteristics). The front fluid tank, molded of VALOX, contains the electrostatic fluid for this printer (chemical resistance). This is not merely packaging, but what is now called designing from the inside, out.

The question now is, what will the plastic designer do that will increase his effectiveness tomorrow? We believe that he will take new materials and make these large complex parts do more both outside and inside.

A recent design for an electronic package by ITT is most indicative of possible paths for tomorrow's designers. The challenge was to produce an electronic enclosure that had to meet the following criteria: UV exposure, general all-element weatherability, internal pressures of up to 24 psi, with a 20-year life cycle, and cost-reduce by combining functions of the current unit. This is a tough job for metal, and until recently, was an impossible job for plastics.

The following illustration shows the design configuration used to achieve these goals.

The center section was molded of LEXAN Structural Foam, while the doors were designed for FL910, a 10% glass-filled polycarbonate foam, which allowed an increased modulus to contain the internal pressures. All parts were molded black for UV resistance, and the center section combined many functions, which enabled ITT to replace a 150-part metal assembly with three engineering structural foam parts weighing 55 pounds.

10% and 30% glass-filled polycarbonate structural foams have been developed in response to designers who have required greater physical properties in larger, more complex assemblies. The products now offer the designer UL 94 V-0 characteristics, modulus to 900,000 psi, heat distortion temperatures to 289°F, and excellent impact.

The same design techniques possible with standard engineering structural foam can be used to greater extent with the newer materials.

Engineering Structural Foam allows greater design freedom with aesthetic styling and molded-in function. Parts consolidation and the combination of function results in cost reduction, which translates to assembly and labor savings. Unlimited part size with inherent structural integrity can be obtained with the use of high performance structural foams.

In designing large, complex assemblies with structural foam, the designer can now achieve rigidity through the use of ribs, gussets, and curved surfaces. Component mounting systems can be developed with molded-in bosses, high standoffs, retainers, and 0° draft printed circuit board guides. To assemble these parts, he can use self-tapping screws, ultrasonic inserts, and solvent or adhesive bonding. Precise critical tolerances, not attainable in molding, can be achieved with the use of machinable inserts. These inserts are used for critical close tolerance center distances, plane definitions, and alignments.

Structural foam business equipment housings are electrically shielded by painting, vacuum metallizing, flame spraying, arc spraying, or creative electrical redesign. The designer should always be aware of the processing criteria for his end product. His focus should be 1/4" walls, an understanding of the flow length of the material used, and an allowance for draft angles. To finish his part with paint, the designer can now use the new high solids urethane paint. This system has helped reduce the standard three-step painting process to two steps. If textured cavities are used during molding, a high quality surface can be obtained with one coat.

These design techniques, used successfully in engineering structural foam over the past four years, are seen by us as the foundation of the advanced designs of tomorrow.

It is common knowledge that you can produce large exterior parts in engineering structural foam that are more cost-effective than plastic and metal, but this is only half the story of recent successful designs. The large interior functional parts are what enable OEM's like NCR, Houston Instruments, Western Electric, Graphic Sciences, IBM, Burroughs, and others to produce totally cost-effective products. The new, greater-strength materials of tomorrow will help continue this development in design by giving new alternatives to the designer.

RF SHIELDING METHODS - COMPARISION OF PROCESSES AVAILABLE TO THE MOLDER/FINISHER OF PLASTICS

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ABSTRACT

The current trend of increased usage of plastic enclosures for housing electrical and electronic equipment has focused attention on the need for economical RF Shielding methods. This paper will present some general information on RF Shielding theory as it applies to plastics, and outline the critical factors that a molder/finisher should keep in mind when considering RF Shielding systems.

Comparisions will be made among various currently available RF Shielding techniques applicable to plastics, with emphasis on RF Shielding performance, environmental test results, and total system economics. Future trends with respect to government regulations regarding RF Shielding (e.g. FCC, VDE, etc.), will be discussed, along with their impact on current shielding systems. Information on new shielding systems, currently in developmental phases, will also be presented.

ELECTROMAGNETIC INTERFERENCE

Essentially, Electromagnetic Interference (EMI), is undesirable interference from radiation, including, but not limited to, such sources as electronic devices, electric motors, or almost any source of electromagnetic energy, natural or man-made. Lightning, for example, is a common source of electromagnetic interference

which routinely causes disruption in radio operation, or in function of sensitive scientific instruments. EMI can range from long wave length, low frequency radiation such as that emitted by some electric motors, to extremely high frequency signals resulting from X-rays. There is sufficient EMI present, even in remote corners of the globe, to cause operational problems in electrical and electronic devices which are not adequately shielded from its effects. EMI includes both magnetic field interference ("H" Field) and Electric field interference ("E" Field). RFI is part of the overall EMI problem which deals primarily with electric field interference in the Radio Frequency (RF) range, from about 10 kilohertz to 100 gigahertz. It is the purpose of this paper to deal only with interference in the electric field, which almost invariably encompasses radiation in the above frequencies. In general, the methods of shielding discussed herein are not effective for magnetic fields.

EMI interference, which may be viewed in the same context as light waves, can be absorbed by a material, reflected by it, or transmitted through it, depending upon, among other things, the electrical conductivity of the material. Nonconductors and semiconductors usually transmit most of the EMI energy they "see", although they may absorb some, effecting dissipation of the energy. While EMI may sometimes be refracted through the material, resulting in a change of path, the total protection offered by a nonconductor or semiconductor is very limited, because little energy is reflected or absorbed. The energy continues substantially unaffected through the nonconductive or semiconductive packages, frequently interfering with operation of the devices inside.

The use of plastics in fabricating enclosures for electronic and electrical assemblies has increased substantially recently. Enclosures made from new engineering

thermoplastics, as well as from many thermosetting plastics, including polyester fiberglass, epoxy fiberglass and similar materials, are considerably less expensive and more desirable in performance than metal cabinets, particularly in such mass production applications as business machines, computer terminals, and automotive body parts.

However, these plastics, being extremely good insulators, do not provide any resistance to the flow of electromagnetic radiation, and will not shield electronic assemblies inside from its effects. Similarly, they will not absorb the radiation that the devices themselves emit. Metal enclosures, will, of course, act as effective shields for most RF radiation because of their inherent electrical conductivity.

SOME SPECIFIC PROBLEMS WITH PLASTIC ENCLOSURES

Shielding - As indicated above, plastics, by themselves, do not have the capability to shield adequately against radiation which may be generated within a device, or stray radiation from outside which may affect operation of the device. Therefore, even though economics now dictate strongly the use of plastics in virtually all cabinetry with relatively complicated designs and high volume production, one must be cognizant of the problems involved, and the most practical means of solving them, within reasonable economic limits. For example, a major problem relating to the burgeoning use of plastics, along with the new and varied consumer electronic devices on the market, is that of stray radiation from one device causing malfunction of another. There have been several reported instances of electronic devices being affected by radio transmissions, such as that from police or citizens band radios. Potentially serious consequences can result from such incidents - it is easy to imagine the effects of an electronic braking system malfunctioning at high speeds in heavy traffic. These problems, and others involving communications interference, have led the FCC and other Federal agencies to take steps to control the amount of radiation

emitted by electronic equipment. One bill would require manufacturers of all Radios and TV equipment to shield against EMI. Other legislation is also under consideration. Table I lists some common sources of interference, while Table II lists equipment which is highly susceptible to EMI. Neither list is all inclusive as designs are constantly changing.

Electrostatic Discharge - An additional problem resulting from the use of plastic enclosures is that of static electricity. While the metal cabinets formerly used provided effective protection against static buildup because of their natural conductivity, plastics will not do so. For example, a person walking across a rug in dry weather can accumulate a charge of static electricity of greater than ten thousand volts. When that person comes near a grounded object--such as the electronics inside a plastic cabinet, the spark will jump to ground, possibly causing malfunction and/or destruction of sensitive electronic components. If the cabinet is highly conductive,--e.g., of metal construction--the spark will usually jump through the cabinet to ground. Although some malfunction of components is possible due to EMI generated by dissipation of the spark, it is usually temporary, and relatively mild compared to the above situation. If the cabinet is completely non-conductive, it is possible that the charge can be transferred to a non-conductive component--a keyboard, perhaps. Switches on the keys could possibly be destroyed by the voltage accumulation.[2]

Several approaches have been used to minimize ESD problems, including reducing the magnitude of the spark by rendering the surface partially conductive, by painting with materials of varying dielectric characteristics, or filling a base plastic with conductive material, to name a few. Effective dissipation of ESD, however, is very dependent upon the placement of electronic components within a cabinet, and other design considerations.

SELECTING THE BEST SHIELD

Each shielding problem should be approached individually. There are two basic approaches that can be used:

(1) Shield the internal electronics, either individually or collectively, by use of metal enclosures, printed circuit board ground planes, "Faraday cages", and the like.

(2) Metalize the cabinet

The first method incorporates various design factors, and may or may not be feasible by itself, from either an economic or technical standpoint. Metalizing the cabinet, on the other hand, is usually--but not always--effective. For example, an improperly designed cabinet, even if it is made of metal, can be an ineffective shield. For this reason, it is imperative that design of a system be such that effective shielding can be obtained with a metal enclosure--before a plastic (or metalized plastic) enclosure is considered.

The degree to which electronic devices require shielding varies greatly. In some noncritical applications, attenuation of 10 decibels (db) may suffice. Other systems may require 50 db or more to operate effectively. (Table 1)[3] Most often, effective RF Shielding requires attenuation of 30 db or more, making surfaces with relatively high conductivities (low resistivities) necessary.

Relationships among shielding effectiveness, attenuation (another way of defining shielding effectiveness), and sheet resistance ("conductivity") are shown in Figures 1 and 2.

Highly conductive materials tend to reflect radiation, much like a mirror reflects visible light. Effective shielding usually requires lining the inside of the cabinet with a metal, in order to get sufficient conductivity to dissipate

the interference. However, techniques such as foil lining have been generally unsatisfactory, particularly with the complex shapes of many newer packages. Methods which have proven effective to date include vacuum metalizing, wire spraying, plating, and metal filled coatings. Conductive composites, a relatively new method of shielding, also merit consideration. Some of the above procedures, however, are very costly, and processes must be selected carefully to provide the degree of electrical stability and overall reliability required over conditions encountered during the life of the product.

SELECTION OF SHIELDING MATERIALS

Assuming that the design of the system is fixed--and is at least adequate to provide effective shielding with a metal cabinet, one can select a shield based upon the following points:

1. Shielding effectiveness
2. Reliability
   a. Adhesion
   b. Environmental Resistance
3. Cost
   a. Materials
   b. Application
   c. Anti-Pollution Requirements

Shielding Effectiveness

A correlation of the sheet resistance of shielding materials to shielding effectiveness enables one to select an appropriate method based on sheet resistance. It must be pointed out here that sheet resistance (measured in ohms per square) is an estimate or approximation of impedance, which is an actual determinant of shielding effectiveness. Approximate shielding effectiveness (attenuation) in decibels is

given by the following equation:

$$SE_{db} = 20 \log \frac{Z_w}{Z_b}$$

where:

SE = Shielding effectiveness (attenuation) in decibels

Z_w = Impedance of air - approximately 377 ohms

Z_b = Impedance of the shield - in ohms per square

Since impedance varies with frequency, one cannot assume that a material with low sheet resistance will necessarily provide a good shield at all frequencies. However, at a given frequency, shielding effectiveness and sheet resistance are generally correlative. Attenuation vs. sheet resistance at 100 megahertz is shown in Figure 2. This relationship makes sheet resistance a reasonably good quality control tool for production, as long as shielding effectiveness numbers, and their correlation to sheet resistance, have been determined for a given system design.

Reliability

The shield must maintain its shielding effectiveness and its adhesion to the plastic substrate throughout the expected life of the product. While there are few meaningful specifications or requirements in this area at present, work is underway by several organizations to develop a workable program.

Cost

Total costs of applying a system must be considered. These can vary significantly depending upon materials costs, applications costs, OSHA and EPA regulations, and special equipment requirements, to name a few. A general idea of comparative costs of shielding by various methods is presented in Table 2.[4]

COMMON SHIELDING METHODS

Foil Lining

The use of metal foil, one of the earliest methods of shielding electronic components, is severely limited by the complex shapes of today's enclosures. While metal foil usually provides an effective shield and is relatively inexpensive, its high cost of application precludes its use on all but the simplest of substrate configurations. An additional problem associated with foil results from its propensity to tear easily, interrupting the integrity of the shield.

Vacuum Metalizing

This process involves the evaporation of a metal film (usually aluminum) in a vacuum, directly on to a plastic substrate, or on to a paint base coat. The film is typically about 20-50 microinches in thickness. While good conductivity is usually achieved with this method, there are several disadvantages. The thin film is easily scratched and has poor environmental resistance unless overcoated. In addition to the substantial investment in equipment, the process is slow, and most substrates require a base paint primer to promote adhesion. These last factors raise the total cost of this process, making it more expensive than many alternative shielding methods.

Wire Spraying

This process involves the deposition of molten metal onto a plastic surface, using either a flame or an electric arc to melt the metal. Several metals are used, including zinc, aluminum, copper, and silver, with zinc the usual choice for low material costs. Excellent shielding is obtained, but specialized equipment is required and there are severe health hazards encountered with the application process. While material costs are low compared to the material costs of most

other methods listed in Table 2, surface preparation is necessary for many substrates. Grit blast surface preparation tends to be inconsistent, and blisters in the metal film have been observed as a result of thermal stress differences between the substrate and the metal film.[5] Base coat primers help to reduce this problem, but they contribute to the final application cost. Wire spray processes are time-consuming (about 1/3 the rate of spray painting) and sometimes exhibit inconsistent results in terms of shielding effectiveness, as a result of blistering or flaking. Although wire spray shielding is the least costly direct metallization process, it does not appear to be an economical shielding technique for mass production of plastic enclosures. This method can be carefully utilized for above average quality shielding requirements (60-90 db. - Table 1). However, there are less costly conductive coatings which can also provide shielding in this range.

Plating

Metalizing plastics by electroless/electrolytic plating techniques is an established process that has been used for years in the manufacture of printed circuit boards, semiconductors, and decorative plastic parts. In general, the process is time consuming, although it is adaptable to high speed production. Plating, however, has several drawbacks. The chemicals used in the process are corrosive and toxic, and the cost of complying with EPA and OSHA requirements is high. In addition, many of the pre-plate preparations are ineffective on some plastics, and will degrade others. A plastic enclosure cannot normally be plated selectively on one side, unless time consuming and expensive masking is used. While spray plating (simultaneous deposition of a metal salt and reducing agent from a spray gun) allows parts to be coated selectively, its history has been plagued by frequent failures, most of which are due to the very thin (approximately 500 Å) deposited film. Spray plating has been declining in popularity in recent years, and is not considered a major factor in today's shielding market.

Conductive Composites

Conductive composite materials contain electrically conductive fillers to provide low cost EMI Shielding.[5,6] The development of such materials is in an early stage, and compounds have been available commercially on a limited scale only. Composites can, in some cases, be produced quickly, and are said to display good abrasion resistance.[7] Shielding of greater than 30db across 10 KHz to 1 GHz has been reported, with 30% loading of aluminum fiber in polyester.[7] However, the sacrifice of mechanical properties--particularly impact performance--at such a loading, limits the use of composite materials. There are widely used substrates, such as structural foam, which may prove extremely difficult to utilize as composite materials. The uneven distribution of filler particles over complex part geometries is of great concern, as well as the effect of the metallic fillers on mold wear. Although they are abrasion resistant, there is presently no evidence that composites are resistant to environmental stresses, nor is it known whether or not the filler materials are subject to long-term oxidation within the plastic. Additional research may yield solutions to some of the problems that exist, and composite materials may eventually offer economical RF Shielding for some applications (Table 2).

Conductive Coatings

This method utilizes paints filled with conductive particles, including graphite, silver, copper, and nickel. Conductive coatings adhere to a wide variety to substrates with little or no surface preparation, since the interface between the metal particles and plastic substrate is less abrupt due to the organic component of the coating. In addition to promoting adhesion, the organic binder of the coating provides a buffer during thermal cycling, as its coefficient of thermal expansion is close to that of the plastic substrate.[8] Generally, shielding effec-

tiveness of 30 to 60 db across 10 KHz to 1 GHz is obtained with a 2-3 mil coating; there are coatings that provide up to 80 db attenuation at some frequencies (Figure 3). Coatings are applied with conventional spray equipment and shielding effectiveness is related to the type of coating, and to the thickness applied.

Silver coatings are reliable, have excellent conductivity, and show good adhesion to a variety of substrates, but they are cost prohibitive. The high cost of silver has led to the formulation of base metal systems of considerably lower cost (Table 2).

Copper filled coatings are a very cost effective shielding method. There are drawbacks, however, associated with their use. Most are not environmentally stable, as copper has a tendency to oxidize upon aging. A system based on a thermosetting epoxy copolymer, which provides optimum electrical conductivity and environmental resistance, is the only known environmentally stable copper coating available. This coating has an average sheet resistance of less than 0.5 ohms per square at a dry film thickness of 2-3 mils, resulting in attenuation of greater than 40 db at most frequencies (Figure 3). However, the system is two-part, requires a bake cure, and must be applied carefully.

While there are several copper coatings available in thermoplastic vehicles, presently none can withstand environmental stress, particularly humidity testing at 140°F. These coatings initially exhibit excellent electrical conductivity and shielding effectiveness, but subsequently lose their shielding properties in the field due to environmental factors.

Coatings filled with nickel appear to be the most widely applicable of base metal coatings. As nickel has less of a tendency to oxidize, it can be incorporated into a wider variety of vehicles than other base metals. In order to obtain optimal environmental resistance and shielding effectiveness, however, the nickel

filler used in coating systems must be modified, resulting in a wide variance in characteristics of commercially available nickel filled coatings. Consequently, nickel-based systems must be evaluated individually to determine shielding effectiveness, adhesion and durability. The majority of nickel systems are air dry systems, and are applied with conventional spray equipment at typical dry film thicknesses of 2 mils, to yield greater than 40 db attenuation at most frequencies. Nickel coatings appear to be the most economical shielding method for a majority of plastic enclosures. There is little or no surface preparation required, in contrast to direct metalization methods. The spray application is adaptable to high speed production, resulting in low labor costs. Cabinets with complex geometries can be coated without fear of incomplete coverage in tight corners. Nickel coatings have been formulated to withstand environmental stress (such as humidity testing at 140°F) and to remain stable with age.

Graphite systems are not as useful for RF Shielding purposes as they are for electrostatic dissipation. These systems are similar to the nickel systems except that sheet resistance is much higher (20-10k ohms per square). Compatible nickel and graphite systems have been effectively blended to obtain relatively high degrees of shielding effectiveness, at low material costs (Figure 4).

SUMMARY

An understanding of alternative shielding methods is necessary to select the most economical and electrically stable shield for an RF Shielding problem. Shields should be tested for shielding effectiveness, durability, and ease of application before a selection is made. Evaluation must include consideration of compatibility with substrate, adhesion to substrate, and operating temperature range. Adhesion before and after environmental cycling should be tested. Humidity testing at 140°F for 72 hours is helpful in determining if the metalization will survive shipping conditions. For example, the temperature inside a shipping trailer in summer can

easily reach 140°F and a relative humidity of 90% or greater. Some shields may lose their effectiveness entirely in these circumstances. The properly selected shield should show little or no change in electrical conductivity after environmental tests.

TABLE 1

QUALITY OF SHIELDING IN DECIBELS[3]

Quality of Shielding	Level of Shielding Effectiveness
Poor	0-10 db
Fair	10-30 db
Average	30-60 db
Above Average	60-90 db
Excellent	90-120 db
Exceptional	>120 db

TABLE 2

COMPARATIVE COSTS OF SHIELDING MATERIALS

	Materials	Application	Total ($/sq ft)
Silver Filled Coatings	4.00-10.00	0.20-1.00	4.20-11.00
Vacuum Metallizing	0.25- 0.75	1.00-4.00	1.25- 4.75
Plating	0.40- 0.75	1.00-2.00	1.40- 2.75
Wire Spray	0.40- 0.80	0.50-4.00	0.90- 4.80
Base Metal Coatings	0.25- 0.60	0.20-1.00	0.45- 1.60
Graphite Filled Coatings	0.10- 0.50	0.20-0.50	0.30- 1.00
Conductive Composites	0.50- 1.00	N/A	0.50- 1.00

Figure 1

SHIELDING EFFECTIVENESS VS. ATTENUATION

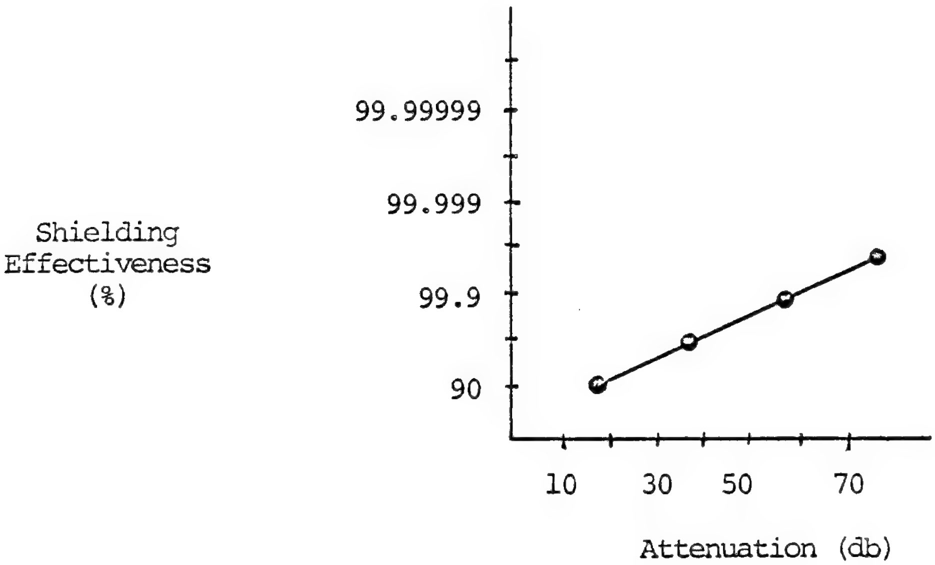
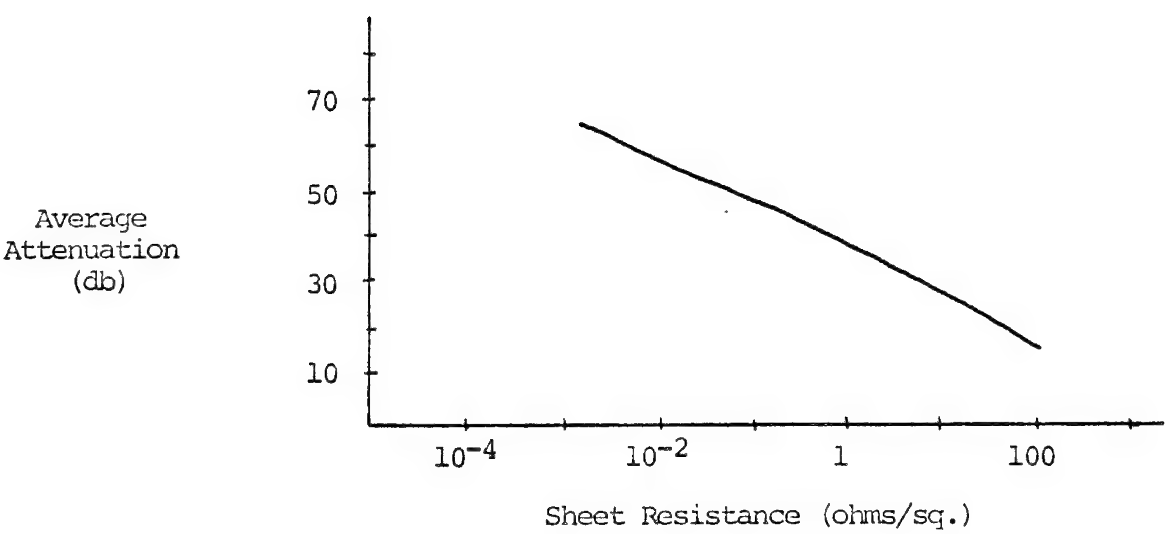


Figure 2

AVERAGE ATTENUATION VS. SHEET RESISTANCE*



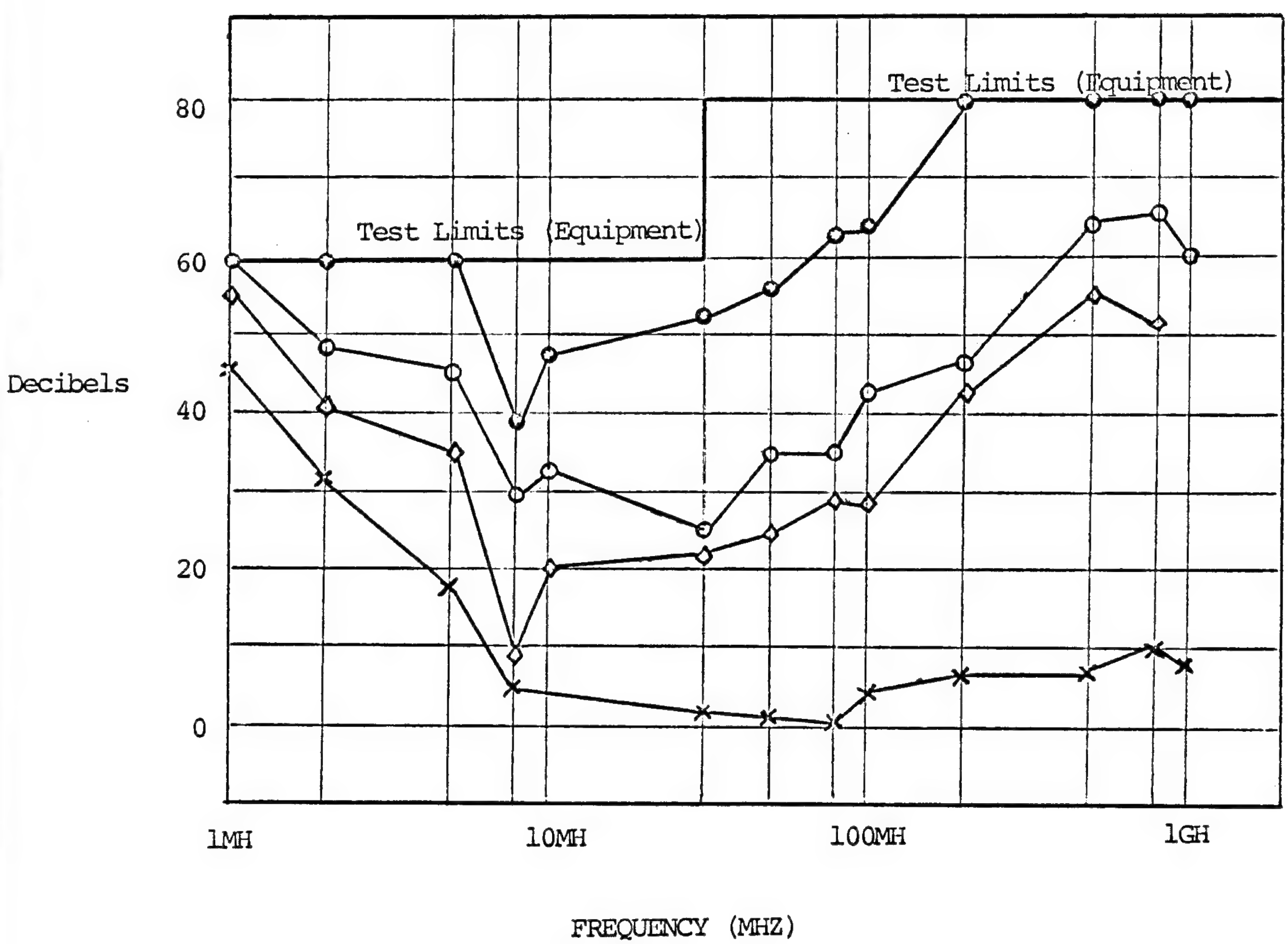
*Reciprocal of conductivity of constant thickness.

Figure 3

SHIELDING EFFECTIVENESS - SELECTED MATERIALS

KEY:

- Copper in Epoxy Copolymer
- Silver in Acrylic
- Silver Spray Plating
- Graphite in Acrylic



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THE BIG BREAKTHROUGH

NEEDED IN

STRUCTURAL FOAM

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A class A finish on injection molded structural foam parts has been as elusive as the "Scarlet Pinpernell". For over ten years engineers in our structural foam community had dreamed of a class A finish and the great markets it would open up for structural foam if it could be obtained -- obtained economically. The markets of class A finish could be automotive, truck, and institutional furniture.

Many ideals have been tried with varying degrees of success and we would like to tell you about the processes that we have tried and the status of these processes.

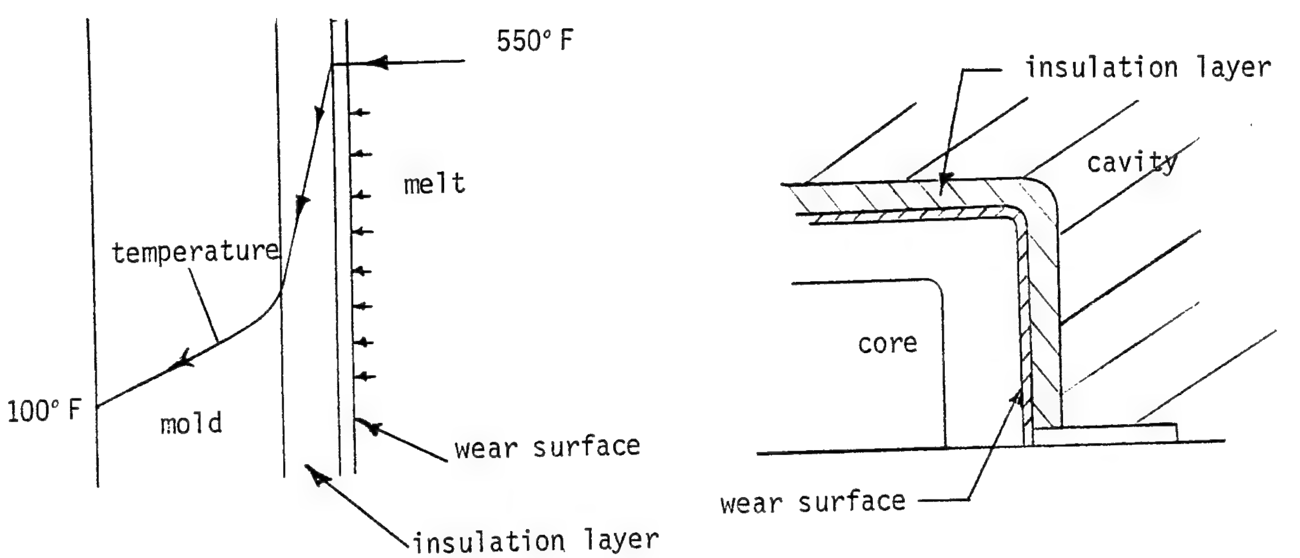
It is a well known fact that evaluating the temperature of a mold beyond the heat distortion temperature of the polymer will give a superior finish void of swirl patterns and pitting. There are two ways of accomplishing this desired result. The first is to treat the mold with a thermal insulating material to retard the slip flow condition between the hot melt and the relatively cold cavity surface.

An insulating material, such as rubber, has produced parts that approach a class A finish. According to the principals of heat transfer and thermodynamics, the capability of such an insulating material depends upon the thermal conductivity and the layer thickness of the material to be used. Poor thermal conductivity of the insulating material and the thicker the layer of the insulating material, the better results are achieved. There

are quite a few candidates that could be used as an insulating material but each has some draw backs. Below is a table showing materials that could be used, their thermal conductivity and their thickness required.

MATERIAL	THERMAL CONDUCTIVITY	THICKNESS REQUIRED
Vulcanized Rubber	0.1 Btu/HR-Ft-°F	0.020 inches
Silicone Rubber	0.1	0.020
Epoxy	0.1	0.020
Polyurathane	0.02	0.004
Ceramic-Glass base	0.5	0.100
-Porcelain	0.5	0.100
-Metal Base	2.5	0.500
Carbon Steel	20.0	

NOTE: Thermal conductivity of carbon steel $\cong$ 200 times of Rubber



However, the vulcanization process of the rubber to the metal is a very tricky process. Plus the fact that the rubber will erode due to the velocity of the plastic going through the gate and runner section causing eventual removal of the rubber from the mold surface.

To try to protect the rubber we sputtered chrome over the surface and this held up quiet well for approximately 100 cycles and then the sputtered chrome started to separate from the rubber. Up until that point in the life of the sputtered chrome the parts were shiny and certainly approaching a class A finish. The conculsion was that due to the problems of bonding the rubber to the metal and the lack of durability of the sputtered chrome, this approach was abandoned. The next materials tried were epoxy and polyurethane and both of these materials again showed good finish. However, the life of both of these materials was short, and again these materials were abandoned. The last material tried was ceramic which was sprayed onto the surface of a hot mold approximately 1700^{0} F. This produced a very smooth and shinny mold surface and the parts obtained by this experiment were exceptionally good. The draw back to the ceramic glass coating was that changing geometry from a flat surface to a contoured surface the ceramic was very difficult to apply. Also the ceramic glass cannot be put on a high carbon steel such as P-20 AISI 4130 but must be applied to a very low carbon steel, .01 carbon and it is difficult to obtain this steel in thickness in greater than two inches. One other problem with the ceramic glass is that at the parting line of the mold there is a build up of the ceramic which has to be ground off resulting in sharp corners and the ceramic glass had a tendency to chip at that point.

Simultaneously with the above tests we worked on a method of heat cycling the mold. A brief summary of what was done prior to our development will be explained.

As I mentioned before, it is a well known fact that to reduce the swirl flow pattern on the surface on an injection structural foam molded part you can increase the cavity surface temperature at least above the heat distortion temperature on the polymer before injecting the melt into the cavity and arrive at a class A finish.

The early approach was to direct high pressure steam through the cooling channels of the mold, elevating its temperature to approximately 350°. However, due to the poor heat transfer of steel it takes approximately five minutes at 250 PSI steam pressure to heat a 12 x 12 x ¼" thick steel cavity from 100° F to 350° F assuming that the water lines or steam lines are located one inch away from the cavity itself. If the mold was made from aluminum the heat up time would be reduced to approximately one minute. Either way is not very economically and as I said earlier we want to obtain a smooth finish, but it has to be at little or no increase in the cost of producing the part at the molding station.

Another thought along the same lines was to only heat the cavity half of the mold. The heat up time was the same, the cool off time was the same, and the added possibility of the differences in expansion between the two mold halfs could cause binding of the two mold halfs, and therefore, difficulty in opening the mold.

Knowing that saturated steam rapidly releases a tremendous amount of latent heat to any cool surface during the condensation process, we decided to stay with the approach using a different technique. Again, based on the technology calculations of thermodynamics and heat transfer principals, the skin of a carbon steel mold cavity could be heated up to 350° from 100° F within ten seconds by the condensing of the saturated steam onto the

surface of the mold cavity directly, at 250 PSI which results in 400^{o} F steam temperature. Since the heat from the steam penetrates only the skin of the mold, rapid heating and cooling can be obtained.

Naturally when introducing saturated steam into the mold cavity, water is generated and must be drained from the mold through a steam trap properly located just outside of the mold cavity and core. The poor thermal conductivity of steel allows only the first few thousands of the surface of the cavity to be heated above the heat distortion temperature of the polymer as shown in the temperature profile graph. The mathematical equation for heat transfer of steam used in this method is as follows:

Nomenclature - - (Definitions for symbols)

$T(x,t)$ = Temperature at any location of the mold at any time, °F

t = time, HR

x = location, Ft

α = Thermal Diffusivity of the mold material, Ft^2/HR

Km = Thermal conductivity of the mold material, Btu/HR-Ft-°F

To = initial mold cavity surface temperature, °F

$T(x,o)$ = Temperature at any location at $t = 0$, °F

$T(\infty,t)$ = Temperature at the extremely far away from surface at any time, °F

$T(o,t)$ = Temperature at cavity surface at any time, °F

q'' = Condensing steam heat Flux, $Btu/HR\text{-}Ft^2$

$\overline{hc}$ = Average heat transfer coefficient of Condensation, $Btu/HR\text{-}Ft^2\text{-}°F$

Tv = Temperature of saturated vapor, steam, °F

$\bar{T}w$ = Average cavity surface temperature, °F

L = Cavity length, Ft

Kl = Thermal conductivity of the condensate, Btu/HR-Ft-°F

μl = Viscosity of the condensate, lbm/Ft-HR

ρ_l = Density of the condensate, lbm/Ft^3

g = Gravitational acceleration = 32.2 Ft/sec^2

= 4.173×10^8 Ft/HR^2

$h'fg$ = $hfg + 3/8\ C_{P_L}\ (Tv - \bar{T}w)$

hfg = latent heat of condensation, Btu/lbm

C_{P_L} = specific heat of the condensate, Btu/lbm - °F

ρ_v = Density of the vapor, steam, lbm/Ft^3

From Prof. Wen Yang, The University of Michigan

Mathematical Differential Equations of Transient Heat Conduction inside the mold body by Steam Condensation on the cavity surface:

$$\frac{\partial T\ (x,\ t)}{\partial t} = \alpha \frac{\partial^2 T\ (x,\ t)}{\partial x^2}$$

$$T\ (x,\ o) = To$$

$$T\ (\infty,\ t) = To$$

$$-Km\ \frac{\partial T\ (o,\ t)}{\partial x} = q''$$

$$= \bar{h}c\ (Tv - \bar{T}w)$$

$$\bar{h}c = 0.943 \left[\frac{\rho_l (\rho_l - \rho_v)\, g\, h'_{fg}\, K_l^3}{\mu l\ \ L\ \ (Tv - \bar{T}w)} \right]^{1/4}$$

Solutions:

$$T\ (x,\ t) = To + \frac{2q''}{K_m} \left(\sqrt{\frac{\alpha t}{\pi}} \cdot e^{-\frac{x^2}{4\alpha t}} - \frac{x}{2}\, erfc\ \frac{x}{2\sqrt{\alpha t}} \right)$$

= Temperature at any location at any time

$$t = \frac{\pi}{\alpha} \left\{ \frac{Km\ [\ T\ (o,t) - To]}{2q''} \right\}^2$$

= Time requirement to heat cavity surface from To to T

If use Aluminum mold, km will be increased and t is increased also.

If use hot air instead of steam, q" will be decreased and t is increased also.

Our first tests using this method were conducted in early 1978, and parts were produced from Noryl, ABS and Polystryene. The results were encouraging, however, pinholes were evident around the sprue area and the residual moisture still retained in the cavity causing streaking at the extreme ends of the parts. The mold was modified to include what we call a decompression valve which instantaneously drops the pressure in the cavity from 250 PSI to 0 exploding the steam and moisture from the mold. This greatly improved the surface finish of the parts and over much of the surface a class A finish was obtained. To date we have had many tests and although we are not ready to say we have fully developed the process, we see that several things are evident: (1) a smooth finish is doable with very little increase in cycle time; (2) that the physical properties of the resulting part are 30% higher than the straight short-shot structural foam injected molded process; (3) that the density reduction is equal to the short-shot process; (4) that we have already obtained parts that can be painted with a two coat system and possible only a textured coat; and, (5) that texturing the mold presents no problem in obtaining a quality part. Our research in this process is continuing because the economics are correct and will substantially decrease the prep time prior to painting at this point in time. I might add that the cost of producing the steam introduced to the mold cavity costs approximately 1½ cents per sq. ft. based upon a power rate of 3¢ per kilowatt hour. The mold costs to prepare it to carry out this type of process is approximately, depending upon the mold size, $3,000 to $5,000 per mold.

Thank you.

SILKSCREEN TECHNOLOGY
WITH
APPLICATION DESCRIPTION

By
Robert W. Carpenter

Silk screening is a technique that has a long history in the decorative plastics field, the basic concepts underlying its applications are well known throughout the industry. The key to developing its usefulness to the processor lies in the ability of the processor to expand the applications of silk screening. This expansion may be the result of some minor alteration in an established area of screening such as the screen mesh or the paint formulation. The expansion may also be the result of extending the capabilities of silk screening into new market areas.

It is necessary to lay some groundwork concerning the production of screens and the finishing process before continuing on into applications.

Production of Screens

A screen is basically a stencil produced on a synthetic cloth or metal screen. The ability to transfer silk screen paint is determined by the mesh of the screen, which is simply the number of threads per inch.

The production of screens has gone through some broad technological advances over the last few decades. The advances have increased the level of sophistication of screening and as a result opened up new markets for the utilization of screening technology.

The screen itself is made of a synthetic cloth, such as polyester or nylon. This screen is coated with several layers of an emulsion which may consist of a polyvinyl glue or thiokol based material. This layer of emulsion is the medium in which the image is produced and it serves the purpose of leveling out the inherent convolutions of the cloth so that the transfer of paint is more consistent and uniform.

The actual production of the screen is accomplished by placing the artwork on the backside of the screen, exposing the entire screen to an intense ultraviolet source, and then washing the screen with water, which removes the emulsion in the area shielded by the artwork.

The production of silk screens is an art as much as a science and the skill of the processors screen supplier could be a limiting factor in developing new markets. The screen supplier should be capable of doing his own artwork, if necessary, and be equipped to touch up artwork, if required. Some screen manufacturers even do some basic research concerning techniques to achieve given patterns and color tones.

The screen is, therefore, one vital aspect of the process that is consistently overlooked, yet may play a major role in the development of a finisher's product line.

Silk Screen Paint

According to one source, acrylics have been the work horses for the silk screening on plastics industry for the last 25 years. Acrylics are easy to handle, accept most pigments readily, are relatively stable and have adequate to good performance parameters for most applications. Silk screen paints, unlike many spray coating materials, achieve adhesion through a paint to surface affinity rather than relying on solvent attack for bonding. As a result, many of the silk screen formulas are identical in many respects. Formulation changes are usually subtle

and are directed at making the coating more compatible with the substrate such as making the silk screen composition more or less polar.

Formulators prefer to utilize slower solvent systems including butyl lactate, diacetone alcohol, butyl cellosolve, carbitol acetate, or SC-150. This gives the individual more flexibility in applying the silk screen material and prevents any possible damage to the screen from solvent attack.

In recent years a concern over the capabilities of acrylics has arisen. In areas that are subjected to constant abrasion, such as the instructional area surrounding a control switch, acrylics were less than adequate. To prevent the abrading of the screened areas, polyester and polyurethane topcoats were utilized to cover and protect the graphics. This was a costly operation and did nothing to affect the actual integrity of the silk screen paint. The answer was to produce a two-part part polyurethane silk screen composite that once converted achieved physical properties surpassing customer requirements.

The screening process itself consists of:
(1) Placing the part to be finished into a holding fixture or nest.
(2) Aligning the screen above the part until the graphics or design are located.
(3) Dispensing a small quantity of silk screen paint onto the screen away from the transfer area.
(4) Drawing the silk screen paint over the transfer area (screen openings) with a squeegee.

In reality each of these simple steps may take a considerable amount of effort. The alignment and adjustment of the nest and screen are critical in achieving an accurate reproduction and the condition of the paint and screens involved must be constantly monitored to insure consistency.

APPLICATIONS

Dead Front

One of the areas where silk screening has played a major role is the development of dead front applications. The dead front effect consists of a panel that appears opaque until backlighting projects an image to the observer. The dead front panel has gained wide acceptance in the appliance, automotive and business machine markets over the last few years. It is most effective when used on control panels and gauges. It is effective in the business machine area because it calls the operators attention to a specific function in process and is useful as a warning device because it indicates singular parameters so dramatically and effectively. In addition, by remaining opaque when not backlit the areas in question do not unnecessarily distract attention unless they are functional.

The dead front effect is produced by screening a background color - usually black - onto the first surface of a panel with good light transmission properties, such as acrylic or polycarbonate. This coating should be as thin as possible while retaining complete opacity. This step produces the dropout areas and graphics that are to be backlit and a heavy film would impair the dead front effect.

After the background color has been applied, a film of translucent black may be sprayed or screened over the entire first surface area of the panel. This process effectively removes the contrast between the dropout graphics and the background color coat.

To achieve transparent colors, tinted pads are screened on the second surface directly behind the graphics to be illuminated.

To complete the panel any visible graphics or legends are screened onto the first surface and a topcoat consisting of either polyester or polyurethane is applied.

Capacitance Control Panels

One of the more recent applications of silk screening has been its use in producing capacitance control panels. Using polycarbonate or acrylic as the dielectric, surfaces A and B form a capacitor; similarly, a capacitor is formed by B and C. Thus, surfaces A, B and C form two capacitors connected in series at point B, which is the control surface of the switch. In operation, the MOS integrated circuit generates a clock signal which it sends continuously to surface A. Through series capacitors AB and BC, this signal is, in turn, coupled back to the MOS circuit as an input. If surface B is touched, body capacitance will sharply reduce the amplitude for the MOS input signal, and the chip will recognize the level change and perform the appropriate function.

To produce the metallic surfaces A, B, and C silk screening can be employed. The control surface B must have extremely high abrasion characteristics and this is accomplished by loading a urethane system with metallics.

The conductivity of the control surface does not have to be extremely high, thus allowing a lower loading factor for the metallics. This is important because the metallics have a tendency to block the curing mechanism of the urethane which, in turn, lowers the abrasion resistance.

One of the problems associated with thermoplastics is their traditionally low dielectric constant. Polycarbonate is typically 3.2 at 10^6 cycles while glass is 7 at 10^6 cycles. This means that the polycarbonate panel will have to be ½ as thick as the glass panel to achieve the same capacitance which is the ability of the panel to transmit the signal.

The future of thermoplastics in this market lies in its flexibility of design and through cost reductions by incorporating adjacent components into one unit.

Halftone

The expansion of applications for silk screening depends in large part on the ability to visualize the flexibility of the technique. For instance, many purchasing agents are hesitant to request silk screening for some intricate, multi-colored woodgrain patterns. If a two color process is used, many of the subtle tones of the grain are often lost and the ticking becomes blurred; and if additional screening operations are required to achieve the effect, then screening may not be a very cost effective finishing method.

In this case the answer lies in the production of the screen itself. A photographic technique can be utilized to produce screen openings of various densities. This results in the depositing of a darker color in an area with a high population of openings and lighter shades in areas where the density of openings is lower. Thus, by screening with a dark brown paint one can achieve several shades or tones. The resulting pattern is an extremely detailed woodgrain with distinct ticking.

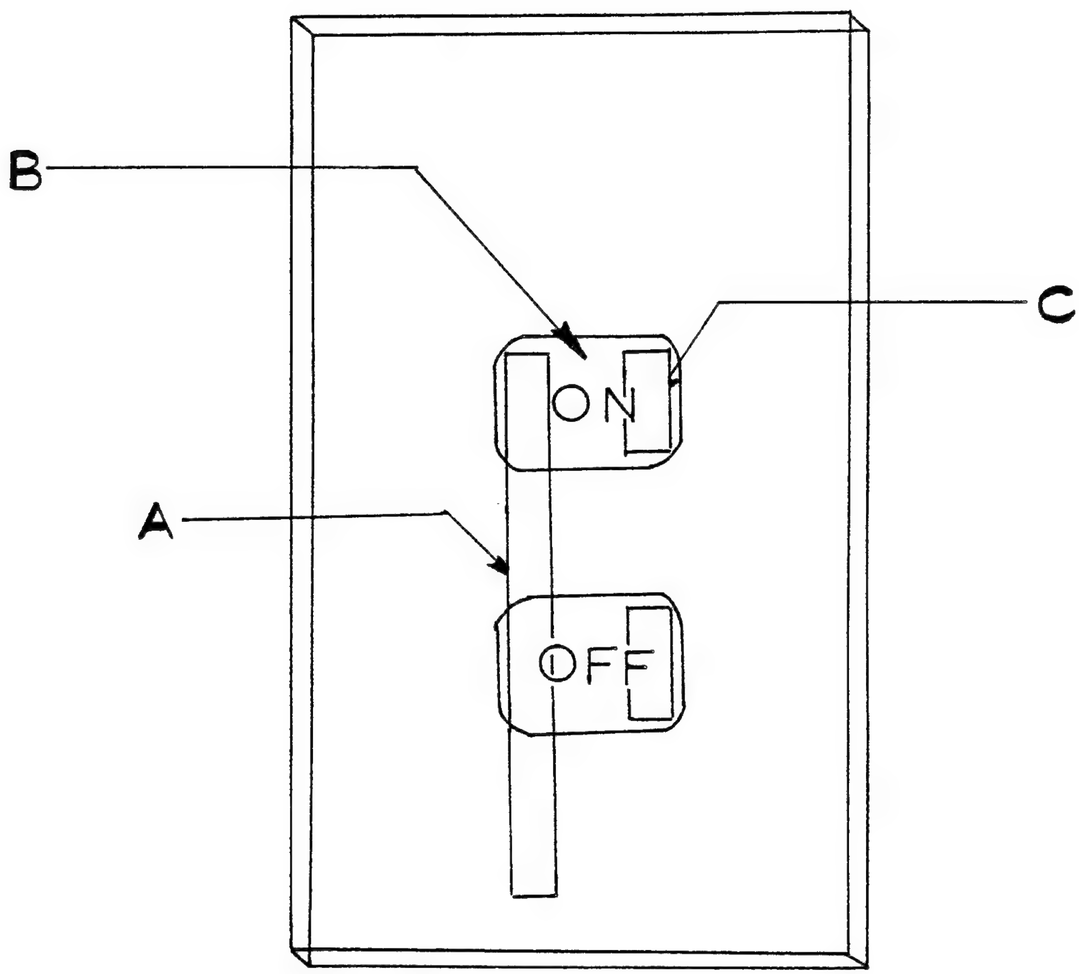
This technique enables a processor to accurately reproduce a sample of veneer with only two screening operations, thus supplying the customer with economics as well as aesthetics.

Shielding

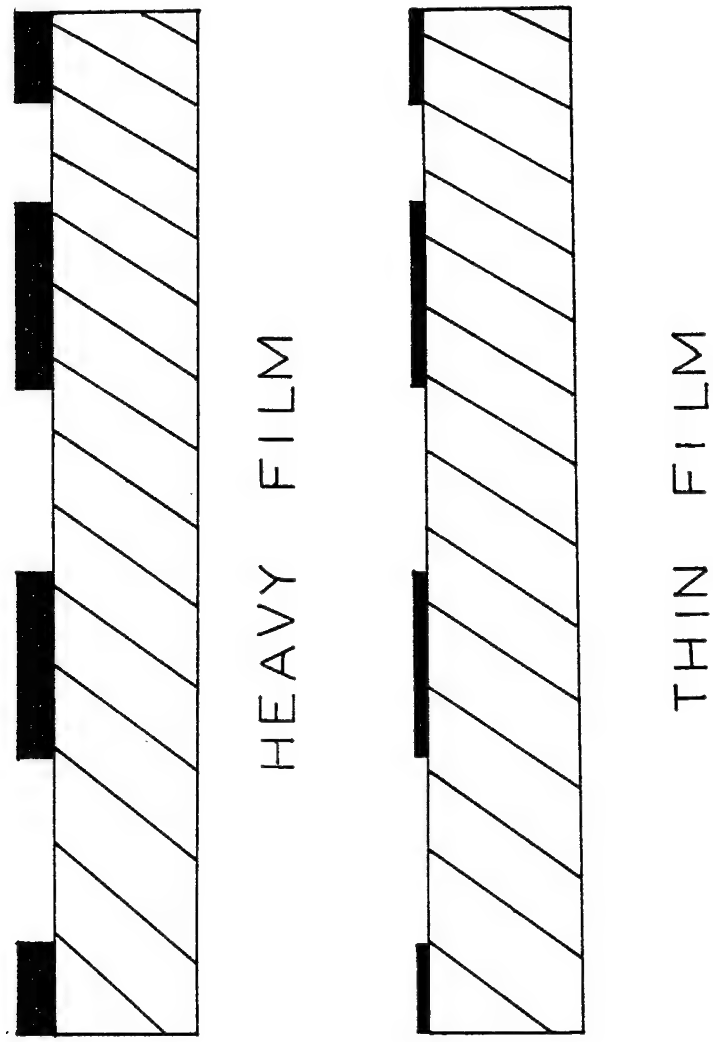
By utilizing conductive coatings, silk screening could also be used for shielding purposes. Applications might include the screening on of protective shields for the microwave oven industry. The pattern involved is dependent upon the wavelength generated by the unit and the thickness of the coating deposited. In testing, the screened on shields have done an adequate job, but the cost is higher than that of conventional glass doors backed by metal plates. Some of the benefits of this method are the design flexibility, the potential to produce a unitized door assembly, and the availability of special materials for specific applications such as Lexan for impact resistance.

Another area concerned with shielding capabilities is the problem of RF1/EM1. Spraying is generally considered to be the mode of operation in applying conductive coatings such as silver, copper, or nickel compositions, but screening could be valuable in areas where the placement and thickness of the deposit are very critical. Such an instance would be a control panel with several windows where the requirements call for applying as much shielding area as possible without impinging upon the window area.

Further developments in marketing strategy may simply be the result of ability of the processor to visualize new applications. For instance, by using carefully prepared screens, acrylic watch crystals may be accurately finished or screening may be used to apply a mask to achieve a special effect. So, while basics of screening may be established, the breadth of applications is only restricted by the finisher's creativity.



CAPACITANCE SWITCH


HEAVY FILM
THIN FILM

LET'S OUTSERT MOLD THAT TOUGH PART

Prepared for Presentation at the

SPE RETEC
Rochester, NY
September 20, 1979

By: David Rosa
Celanese Plastic Materials Company

INTRODUCTION

Outsert molding offers a method for reducing the cost of manufacturing mechanical assemblies by combining plastic and metal, and utilizing specific advantages of each material. Basically, the outsert molding technique consists of placing a stamped metal base plate into a mold and injection molding one or more plastic parts onto the metal plate in one operation.

Stamped metal assemblies are often comprised of many individual components mounted on a metal base plate. The manufacture of these individual components and the assembly of these components into a finished part is often a labor intensive and costly process.

The aim of outsert molding is to reduce the cost of manufacturing stamped metal assemblies, which are produced entirely from metals and consist of functional components mounted on a metal base plate, by replacing all the secondary operations by one injection molding operation. Outsert molding permits the combination of several parts of an assembly into one outsert molded part. In addition, the need for plating of metal parts for corrosion protection is eliminated.

STEPS REQUIRED FOR STAMPED METAL ASSEMBLY FABRICATION

The following steps are generally involved in manufacturing stamped metal assemblies:

Part	Processing Steps
1. Stamped Metal Plate	a. Blank Punching b. Hole Punching c. Bending
2. Pin	a. Machining b. Cold Heading
3. Screw	a. Tapping b. Threading
4. Tube	a. Welding

STEPS REQUIRED FOR STAMPED METAL ASSEMBLY FABRICATION (continued)

Stamping of the metal plate (Step #1) involves only punching and bending operations and is generally considered inexpensive. However, pins, bushings, screws, tubes and other parts (Steps #2, 3 and 4) must be attached to the metal plate as secondary operations such as welding, or cold heading. When several secondary operations are needed in the assembly of a part from a stamping, the cost of these operations combined with the cost of the pins, screws or tubes, may be significantly greater than the cost of the stamping itself. These are parts for which cost savings may be realized by the use of outsert molding.

STEPS REQUIRED FOR OUTSERT MOLDING

The outsert molding technique involves injection molding onto the metal plate of all the parts which would otherwise be made in metal by the expensive secondary operations previously noted. There are four steps required for outsert molding which will be reviewed:

1. Preparation of the metal plate

2. Design of the injection mold

3. Designing parts for molding onto a metal plate

4. Injection molding

1. Preparation of the Base Plate

The base plates for outsert molding are normally stamped from steel, aluminum or copper, although other materials such as plastic base plates can also be used. Progressive or combination dies are often used for stamping of the metal plates. Closer tolerances are possible with combination dies, as feeding faults cannot occur. The metal base plates used for outsert molding are usually in the thickness range of 0.040"-0.080", with a tolerance of $\pm$ 0.002".

In addition to the holes used for molding, two other holes must be stamped into the plate. These will be used for mounting the plate onto two cylindrical pins in the injection mold and will determine the accuracy of the molding locations on the metal plate (see Figure 1). Therefore, the precision of these locating holes is extremely important. The locating holes should be separated by at least 1/2 the length of the metal plate and the distance between them should be controlled to a tolerance of $\pm$ 0.001" per 4" length.

STEPS REQUIRED FOR OUTSERT MOLDING

1. Preparation of the Base Plate (continued)

After stamping, it may be necessary to restraighten the metal plate. This can be done by putting it through a series of levellers as shown in Figure 2.

The final step in the preparation of the metal plate is to degrease it in a cleaning solvent. This will avoid any adverse effects of the grease in the molding operation.

2. Design of the Injection Mold

Molds designed for outsert molding are either of the three-plate or hot runner type. These molds allow multiple gates to feed the various components of the outsert molding. An example of a three plate mold is shown in Figure 3.

There are two methods for holding the stamped metal plate in the injection mold; the sandwich method and the cavity method. As the name implies, the sandwich method simply involves clamping the metal plate between the two mold halves (see Figure 4). The cavity method is used when molded parts are formed by the edge of the metal stamping or extend beyond the stamping.

Support Post - Steel support posts are needed near the edges of the mold, as shown in Figure 5, to help absorb and distribute the clamp force so as not to damage the metal stamping. This is especially true if the plate is made of a soft material or if the plate area is very small in comparison to the surface area of the mold. The height of the support post should be approximately 0.001" less than the plate thickness. This allows the mold to close on the plate (without damaging the plate) to prevent flashing during the molding cycle.

Knock-Out-System - A well balanced knock-out system is required to prevent deformation or distortion. Knock-out pins must be provided near the locating guide pins, on other areas of the metal plate, and on the molded parts.

Draft - Draft or taper will also aid considerably in the ejection of a part from a mold. The deeper the draw the more draft will be required. A minimum of 1/2 degree taper per side is generally satisfactory.

Venting - Standard mold venting techniques are perfectly satisfactory for outsert molding. Venting is necessary to allow air and gases inside the mold cavities to escape as the molten material enters. Inadequate venting may result in incomplete filling of the mold or in burning of the material from the compression of the air in the cavity as the cavity is filled.

STEPS REQUIRED FOR OUTSERT MOLDING

3. Designing Parts for Molding onto a Metal Plate

Vertical Wall Sections - Long vertical wall sections must be avoided wherever possible since the difference in shrinkage between the free section and the section attached to the metal plate will result in a highly stressed part, or in distortion of the molded part or the metal plate. This problem may be alleviated by breaking the long wall up into several smaller sections, each part individually anchored to the plate through one stamped hole at the center of the part. The stamped hole may be oblong in shape to prevent any twisting action. This technique allows uniform shrinkage of each individual component without distortion (see Figure 6).

Pins and Bushings - When molding both pins and bushings it is recommended to have three ribs, 120° apart as shown in Figure 7. These ribs may either join a flange at the base as shown in Figure 8 or they may be anchored to the metal plate through stamped holes as shown in Figure 7. The ribs provide additional strength, roundness and straightness to the molded bushings.

When required, parts can be molded without ribs, depending only on the bottom flange for support (see Figure 8). However, it is advisable to have the stamped hole in the metal plate as large as possible to properly anchor the part to the plate. In addition, a metal pin may be molded into the plastic part if needed for a functional purpose (see Figure 9).

Shrinkage and Tolerances - The mold shrinkage should be calculated individually for each part on the metal plate. However, when using shrinkage factors to determine distances between individual components on the plate, the shrinkage is not measured from the center of the molded part. Instead, the center of shrinkage will occur at the anchor point (see Figure 10).

The tolerance range capabilities for outsert molded parts are comparable to those obtained with stamped metal assemblies.

STEPS REQUIRED FOR OUTSERT MOLDING

3. Designing Parts for Molding onto a Metal Plate (continued)

Runner Design - In many cases, it is advantageous to connect two or more components on the metal plate by a runner and gate into that runner, rather than gating into each individual component. When they do not interfere with the function of the molded assembly the runners may be left in place as molded. However, the material shrinkage of the runner may cause the metal plate to bow, the connected parts to tilt toward each other, or the runner to break (see Figure 11). This problem may be alleviated by the use of curved runners rather than straight runners (see Figure 12). The curvature will absorb the shrinkage so that the functional parts are not affected.

When it is required for a functional purpose, the runner may be made flush with the metal plate by cutting a channel into the metal plate and using it as the runner, as shown in Figure 13.

As-Molded Moveable Parts - One of the outstanding advantages of outsert molding is the ability to mold moveable parts directly onto the metal plate in one injection molding operation. These include parts such as springs, gears and cams. This technique can provide substantial cost savings when compared to a similar system made up of several metal parts. Examples of as molded moveable parts are shown in Figure 14.

The holding strength onto the metal plate of moveable parts, such as gears and cams, must be reduced to facilitate rotation. This may be accomplished by making the collar on the underside of the part smaller and thinner than the part on the top side (see Figure 14).

4. Injection Molding

The molding conditions for outsert molding are the standard injection molding conditions recommended by the resin manufacturer. Typical injection molding conditions for the Celanese Engineering Resins are shown below:

	Celcon * Acetal Copolymer	Celanese Nylon	Celanex * Thermoplastic Polyester
Melt Temperature	360-390°F	520-550°F	480-510°F
Mold Temperature	150-200°F	150-200°F	150-200°F
Injection Pressure	Mid-Range Setting	Mid-Range Setting	Mid-Range Setting
Injection Speed	Mid-Range Setting	Mid-Range Setting	Mid-Range Setting

*Registered Trademarks

ECONOMICS

Outsert molding reduces manufacturing cost versus stamped metal assemblies by replacing all the secondary operations with one injection molding operation. The number of components in an assembly unit determines the level of savings possible. In general, the greater the number of components being replaced, the greater the potential savings.

Table 1 shows the actual cost savings realized by using outsert molding versus a stamped metal assembly in a tape recorder sub-assembly. In this case a 41.5% cost savings was realized.

APPLICATIONS

The outsert molding technique has brought/and can bring significant cost savings into many applications. Some examples are listed below:

- Computers and Calculators
- Copiers and Typewriters
- Tape Recorders
- Radio and Television Equipment
- Toys
- Cameras and Projectors

SUMMARY

Outsert molding aims to reduce the cost of manufacturing stamped metal assemblies by combining plastic and metal utilizing the advantages of each material. The outsert molding technique required the injection molding onto a metal plate of many functional components in one operation. This method may provide cost savings versus stamped metal assemblies since all of the expensive secondary operations are replaced by one injection molding operation.

FIGURE 1

Position of Locating Holes

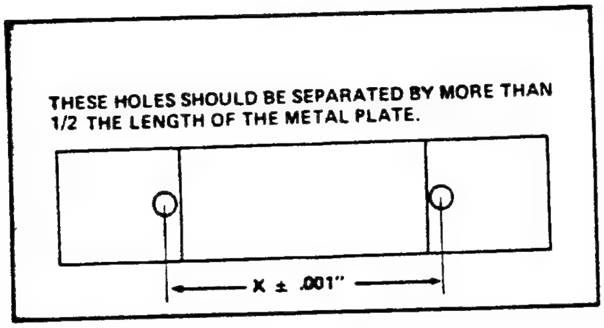


FIGURE 2

Levellers for Restraightening

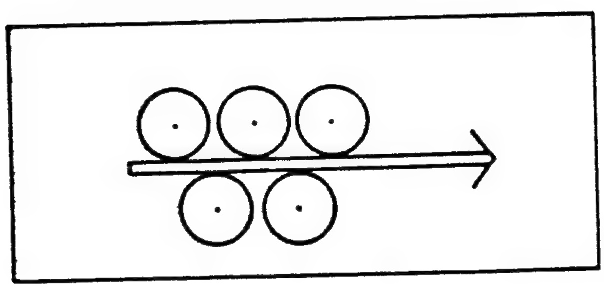


FIGURE 3

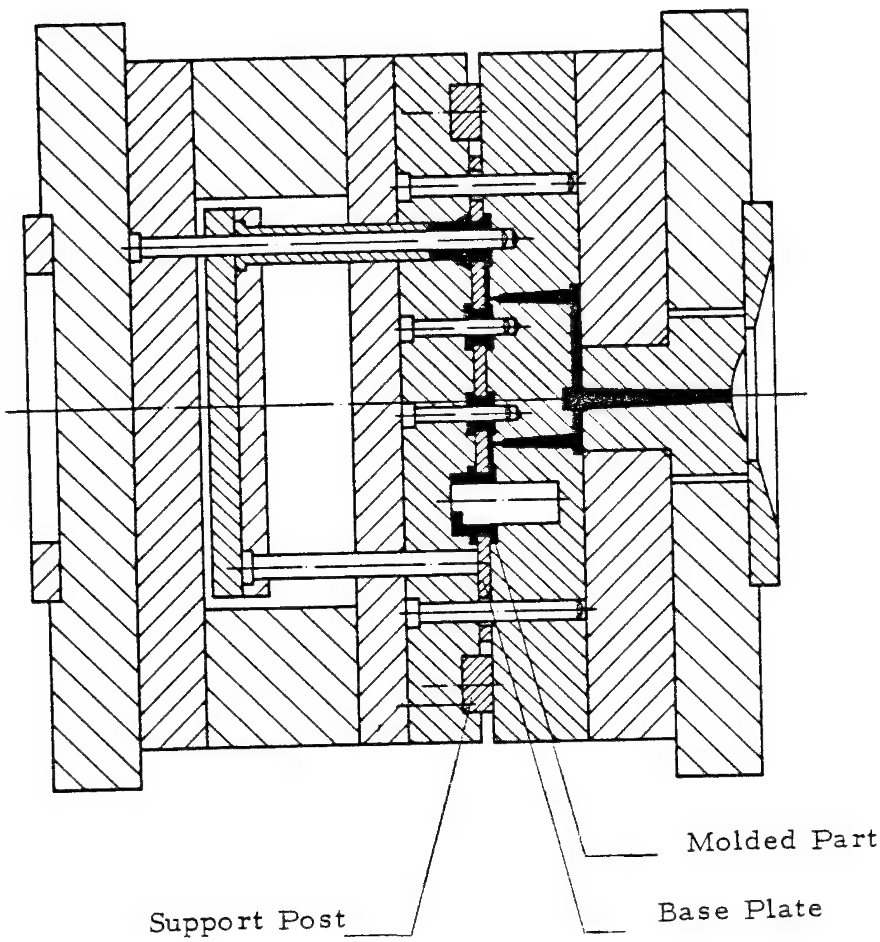


FIGURE 4

Methods for Holding Plate in Mold

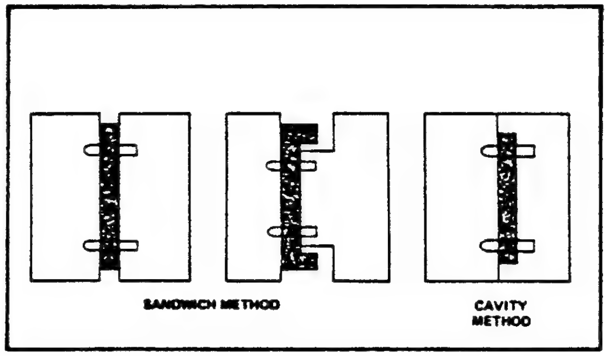


FIGURE 5

Use and Position of Support Post

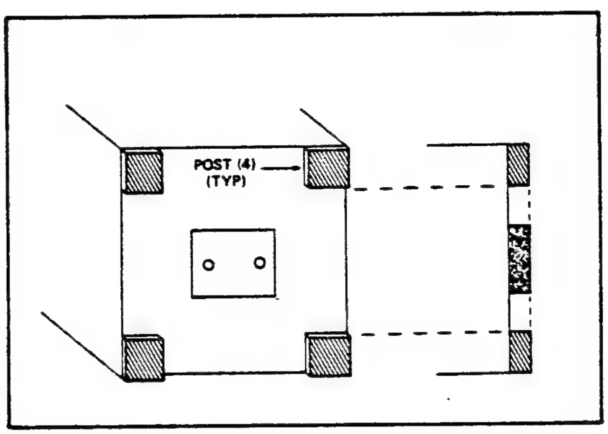


FIGURE 6

Design of Vertical Walls

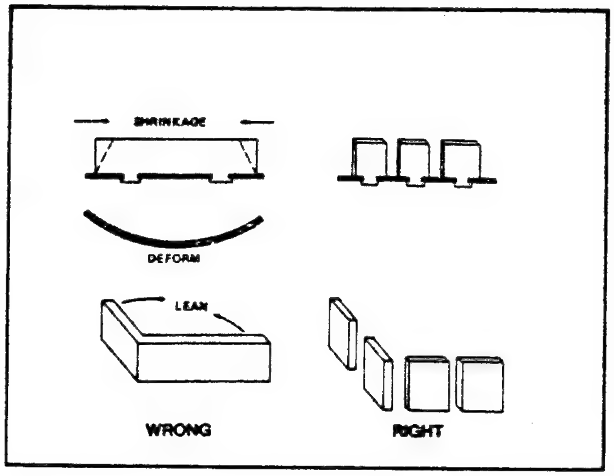


FIGURE 7

Recommended Design for Pins and Bushings

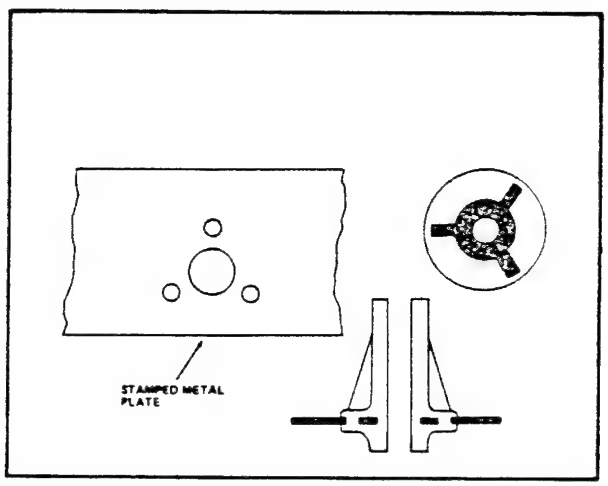


FIGURE 8

Alternate Post Designs

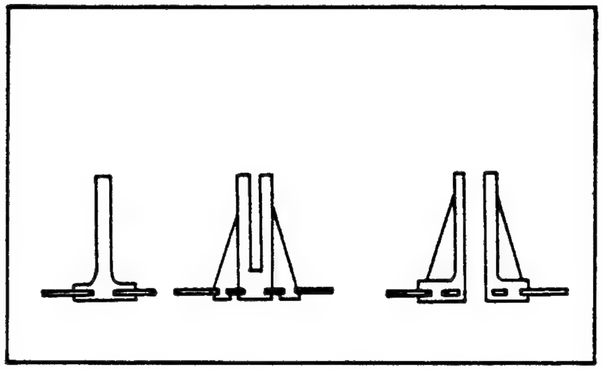


FIGURE 9

Molded-in Insert

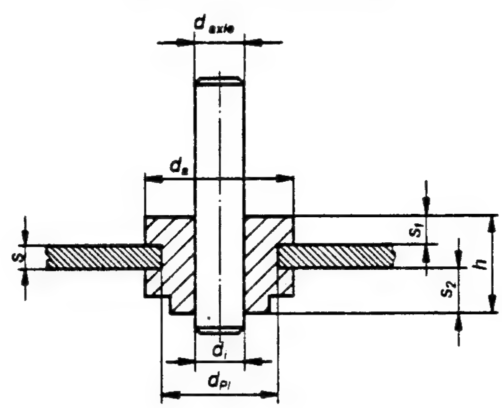


FIGURE 10

Estimating for the Center of Shrinkage

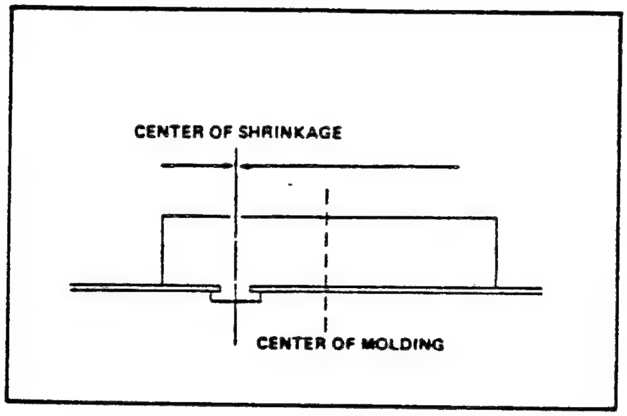


FIGURE 11

Recommended Runner Design

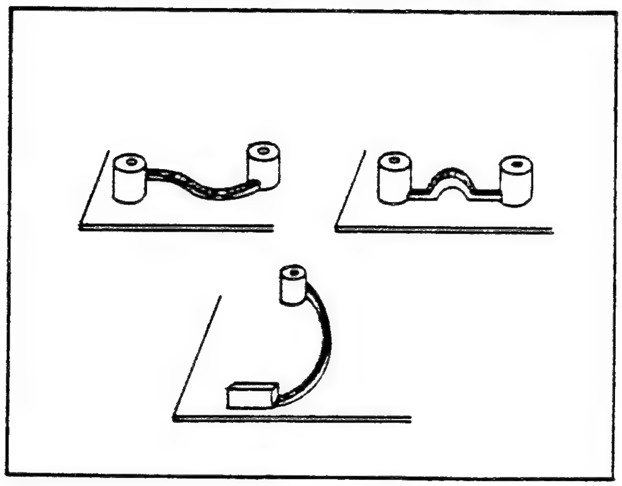


FIGURE 12

Potential Problems with Straight Runners

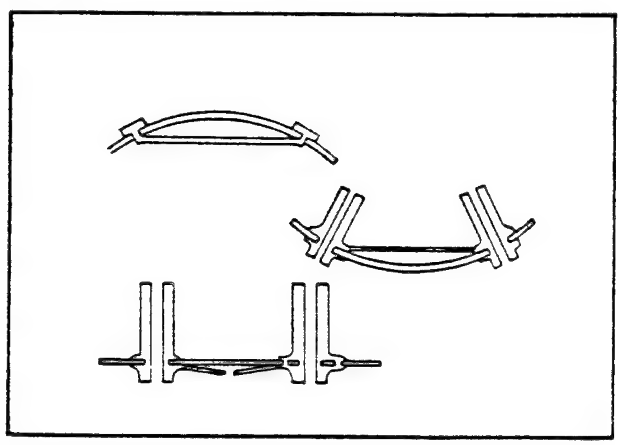


FIGURE 13

Design for Runner Flush Plate

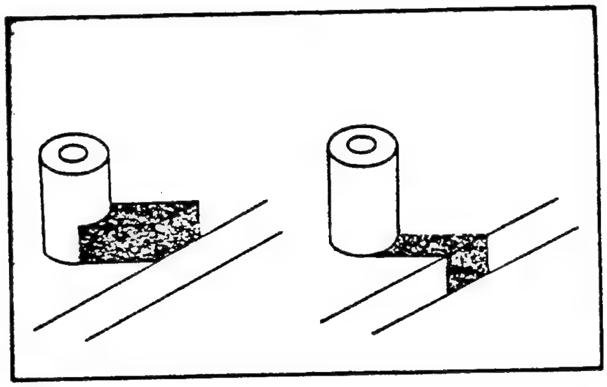


FIGURE 14

Example of As-Molded Moveable Parts

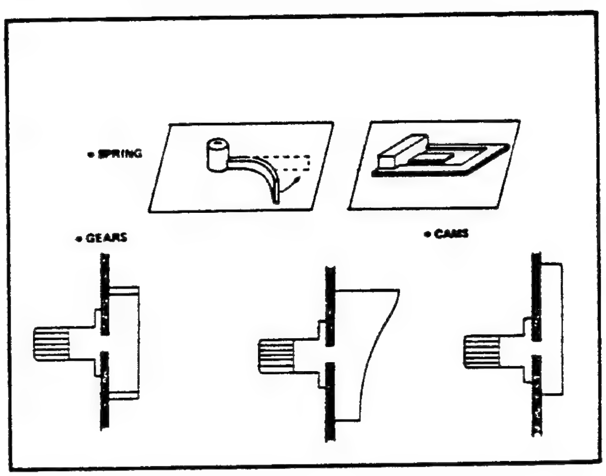


TABLE 1

Cost Analysis of Tape Recorder Sub-assembly

		COST PER 1000 PIECES ($)	
		MATERIAL	PROCESSING
STAMPED METAL ASSEMBLY			
SHEET METAL (19 grams)		16.30	
STAMPING	(BLANK)		5.00
	(HOLE PUNCHING)		7.50
	(MOLD DEPRECIATION)		6.65
PLATING			22.50
PINS (2.5 grams)		50.00	
MACHINING & TAPPING			70.00
COLD HEADING			70.00
TOTAL COST		66.30	181.65

		COST PER 1000 PIECES ($)	
		MATERIAL	PROCESSING
CELCON MOLDING			
METAL PLATE		16.30	
STAMPING	(BLANK)		5.00
	(HOLE PUNCHING)		7.50
	(MOLD DEPRECIATION)		6.65
PLATING			22.50
CELCON ACETAL COPOLYMER – BLACK (5 grams)		10.65	
INJECTION MOLDING 20 SEC. CYCLE			72.00
MOLD DEPRECIATION			5.00
TOTAL COST		26.95	118.65

SPE RETEC - Rochester, New York

September 20, 1979

GETTING THE MOST FROM SMC

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ABSTRACT:

Today's applications of polyester sheet molding compound (SMC) are influenced by "value engineering" more than ever before. The purpose of this paper is to point the way to getting the most from this unique material. The methods are basic, but, as a whole, they must interact. We must design for economy as well as function and re-evaluate subtle differences in material substitutions to improve strength-to-weight ratios. As we replace metals and other materials, there is great need to consolidate parts rather than create an assemblage of pieces.

INTRODUCTION:

The rapid growth of sheet molding compound since it was introduced in the late sixties, has been primarily due to its excellent performance in molded parts for fascia applications such as automobile front ends, trim panels, appliance housings, business machine enclosures and most recently complete typewriter housings. There has been an all-out race to develop a variety of new materials to qualify SMC in a myriad of new applications mostly by vendors and custom molders. Meanwhile, concurrently with material development, the designers and manufacturing engineers have recognized the advantages of SMC and are pressing the industry for higher strengths and lower cost finishing while requiring SMC to carry its own cost-performance burden.

DESIGN:

Today's parts require very precise tolerances such as 0.5 mil per inch in linear dimensions between ribs and/or hole centers and a similar tolerance over several indicator reading points to determine flatness.

Several years ago the materials were not available to control shrinkage and

warp as it is controlled today. Much of the truly cost-effective good performance now comes from innovative design. Parts must be designed for easy removal from a mold while at the same time be of a thickness that presents sufficient stiffness at minimal weight and the shortest cure time. These things may be accomplished by following a few design guidelines as follows:

Draft:

Minimum draft should be one-half degree or more. More draft is always desirable to assist material flow and part removal, but one degree is considered normal. When deep free-standing ribs are specified, there are advantages to using the least amount of draft to reduce the thickness of the rib base which reduces cure time. If more draft is desired, then a second approach is to design the top edge of the rib as thin as practical to result in a thin base section. When texture is included in the mold surface, the best rule for proper draft is to specify one degree for each mil of texture depth then add one additional degree to release the surface texture without scuffing.

Nominal Thickness:

In design of molded plastic parts, all wall sections should be kept as thin as possible to reduce weight and cycle time. Thermoset polyester molding compounds usually are molded in thicknesses of .100" to .125", but this must be increased in specific areas to attain stiffness.

Ribs for Stiffness:

If a part is designed with economy in thickness, there is a possibility that stiffeners must be added. This is accomplished by ribs in the direction of required stiffening or around the perimeter to enhance both stiffness and flatness. Section elevation changes are the most efficient stiffeners if these can be fitted into the styling. Gusseting at the plane change in such

a design can give strength values equal to 20 times the flat thickness values.

Bosses and Fasteners:

Bosses are generally designed to accept locating pins or fasteners and should be considered as a rib that forms a circle. When used to accept screws or inserts, the wall thickness becomes critical. The following chart represents the recommended hole sizes for three types and six screw sizes generally used in thermosetting SMC parts: (Ref. SPI paper No. 2F 1977 F. L. Massey).

Screw Types: Hi Lo, Type B and Type BT or 25

Screw Size:	#6	#8	#10	1/4"	9/32"
Hole Dia.:	.116"	.125"	.160"	.213"	.234"
Boss Dia. (Min.):	.380"	.410"	.475"	.625"	.750"
Screw Depth:	.500"	.625"	.750"	1.00"	1.00"
Max. Torque Inch Lbs.:	13	15	20	25	25

The above are recommended for good cost-performance. If greater torque or higher strengths are required, then gusseted or thicker bosses are needed.

MATERIALS:

Sheet molding compound or SMC refers to both a material and a process for producing polyester molding compound. The material is composed of an unsaturated polyester resin, usually an isophthalic system, which may be modified with a thermoplastic shrinkage control additive. The resins are catalyzed for high temperature (290^{o}F) molding and combined with mineral fillers, i.e. alumina trihydrate in U.L. compounds, to which fibrous glass strands typically one inch in length are added at the correct percentage.

During processing, a chemical called a thickening agent is added to increase viscosity and enhance the handling and molding properties.

Processing films are removed and the SMC cut to precisely determined mold charges which are placed on the mold surface for compression molding or in the charging chamber for transfer or injection molding.

SMC is now available in nearly all grades required for chemical resistance, fire ratings, electrical properties and structural performance. It is also available in controlled shrinkage compounds which can be specified from .003"/ in. down to .0005"/in. and still have the aforementioned properties. Injection moldable grades of SMC are finding acceptance in high volume applications permitting close tolerances on small business machine and electrical parts. These same compounds perform extremely well in transfer molding and attain slightly higher mechanical properties.

Structural SMC is a material development in which very high glass content and/or orientation is utilized for high strength members of minicomputer modules. These compounds usually start at 50 percent random chopped strand for good multidirectional strength (SMC-R-50) and by adding continuous uncut glass strands at various blends, i.e. (SMC-C-50 R-15) a resulting directional strength is added and may achieve flexural modulus nearly double that of (SMC-R-20) standard business machine housing compound.

Sheet molding compounds which may be specified for business equipment or electrical application requiring special Underwriters Laboratories standards, are readily formulated for each specified property. Items requiring 94-VI are available at slightly lower costs than 94-VO due to the price difference between calcium carbonate and alumina trihydrate fillers. Parts requiring 94-5V will carry a higher price for the SMC since it is necessary

to use halogenated resins and expensive synergistic compounds for flame retardancy to attain this standard as well as the ASTM radiant panel rating. Cost savings can be realized by being very specific as to flammability, color pigmentation and ultra-violet stability when specifying SMC types with the molder or compounder.

PROCESSING:

In producing components for business equipment and electronic data processing assemblies, there are three primary molding methods usually used for thermosetting polyester systems including sheet molding compound. These are: compression, transfer and injection, which are characterized as follows:

Compression Molding:

Compression molding uses the mold cavity to force the SMC charge into all sections of the mold under hydraulic pressure of about 1,000 pounds per square inch over the projected area. Tools are usually made of AISI-4140 or P-20 steel and hard chrome plated to handle the above pressures and flow-out. Side cores and small slides will account for molding of holes or bosses in the periphery of the part which are not in the press movement direction. Cores or slides are not recommended in the male or force section of the tool. When the tool is closing under the above pressure, some of the molding compound will reach the edge before the mold is completely closed, therefore, it is necessary to incorporate matching by-pass edges which seal the mold halves to a tolerance of .002" to .004" during the final pressure build up.

This molding process produces the highest mechanical properties since the glass fiber reinforcement is not subjected to degradation caused by flow through narrow orifices. Also, the compression system permits molding of very large parts and allows thin-wall design.

Transfer Molding:

This process uses either vertical or horizontal presses and contains provision for a transfer cylinder through the stationary platen. The mold has a corresponding cylinder and piston in one mold--half into which the SMC charge is rolled and inserted prior to closure of the mold. This system permits flow of the compound into a closed mold and offers the advantage of cams and slides as well as minimized flashing. Parts made in the transfer process exhibit excellent control of dimensions and, although they are slightly lower in impact strength than compression molded parts, they exhibit less porosity.

Injection Molding:

The development of injection molding of thermosetting polyester SMC is relatively new and the process is rapidly finding increased usage. Injection molding machines for thermosets generally use an injection barrel which automatically retracts from the heated sprue bushing to prevent precure. The machines can be either screw or plunger injection systems and must operate with the mold at a temperature of about 300°F and the barrel temperature adjustable from 70° to 200°F.

The injection process presents several advantages such as high pressure packing, closed mold processing, which allows cams and slides, high-speed automated molding and less finishing cost due to reduced flash. An additional benefit is very efficient multiple cavity molding of small parts. Although injection molding of SMC produces the lowest impact strength of the three processes, since the material is forced through small orifices and runners, acceptable parts can be obtained by adding ribs, bosses and/or thickness. The very high molding pressure produces very uniform reproducible parts.

SUMMARY AND CONCLUSIONS:

The business equipment market is highly influenced by technology. Our market research indicates that those manufacturers who have been able to apply new advances in SMC technology have maintained a leadership position in introduction of new and unique products.

Material selections are influenced by the standards for performance imposed on the final product, usually by Underwriters Laboratories or consumer safety agencies. Several custom molders and compounders have the technology to assure compliance.

Processing methods are selected based on annual volume, parts required per shift and the best cost advantage in finishing. High speed molding processes may not be applicable to low volume high precision parts, but must be considered for high volume non-critcal applications.

The business equipment market has been divided among a handful of companies, all decentralized, where material decisions are made at the individual product location. This calls for maximum effort in information sharing within a company to gain the most benefit from SMC.

THERMOSET POLYESTERS
AN EFFECTIVE ALTERNATIVE TO DIE CAST ALUMINUM IN BUSINESS EQUIPMENT APPLICATIONS

by

Stephen Ricks

ABSTRACT

This paper will discuss the evolution of thermoset polyesters as replacements for die cast aluminum in business equipment applications. It will also discuss performance requirements, cost structures, and material availability. The molding processes which allow for replacement of aluminum die castings are also defined. Finally, three significant programs recently tooled in thermoset polyester will be described. These include one external program and two internal programs.

INTRODUCTION

Application of thermoset polyester as a replacement for die cast aluminum is not a new technique for cutting costs while holding close tolerances. Prior to 1971, external parts were applied because of their strength and moldability into aesthetically attractive shapes. In early 1971, the idea of using thermoset polyester for internal, mechanical type parts was explored by several business equipment manufacturers. One manufacturer decided to tool parts for a new machine based on approximately equal tooling costs and significant part cost reductions. Other design objectives which were met were weight reductions, dimensional stability, and low shrink rates available in low profile grades of material. This program has been followed by numerous others which have broadened the acceptability of thermoset polyester as an engineering material.

More recently, opportunities have been expanded by effective utilization of thermoset polyester properties. External parts are not only designed for cosmetic purposes, they also can incorporate structural features which reduces assembly costs. Internal parts, on the other hand, can be produced with close tolerance features in larger sizes than ever

before. Although die cast aluminum is stronger and has excellent machining properties, thermoset polyester moldings can be functional and have tight molded-in tolerances. The cost savings associated with molding versus casting and machining will be increased if current trends in energy consumption and tight supply of aluminum continue.

PERFORMANCE CRITERIA

Business equipment parts demonstrate the classic metal-replacement argument. Fabrication and assembly costs, so high for metals, are slashed by the use of plastic materials and processes.[1] Sheet and bulk molding compound thermoset polyesters allow molding of complex parts studded with bosses, inserts, pins, and other features for accommodating a variety of metal and plastic parts.

The design engineer is charged with deciding on the material and process which meet a number of different performance and cost criteria. Several key factors influence the design engineers evaluation of functional requirements. In a recent study of the die casting industry, the most frequently mentioned characteristics required of materials and processes were: 1) flexural strength and rigidity, 2) impact strength, 3) heat resistance, 4) flammability rating, and 5) weight.[2] In addition, on close tolerance applications, the coefficient of thermal expansion, shrinkage, dimensional stability, and thermal/electrical conductivity are important considerations. Table I compares these properties for bulk and sheet molding compounds (BMC/SMC).

In general, plastic materials also exhibit a much lower modulus of elasticity in flexure than die cast aluminum. It is interesting to note, however, that simple beam deflection varies inversely as the cube of beam depth. By doubling the wall thickness of a BMC/SMC sample, it can have a stiffness equal to that of die cast aluminum. This relationship permits selection of a minimum wall section in BMC/SMC, and incremental increases in localized areas to obtain the designed functional strength.

Impact strength of BMC and aluminum are roughly equivalent. Heat resistance, although lower for thermoset polyesters, is often more than adequate for use as a mechanism or cover type part. The thermal coeffi-

cient of expansion of thermoset polyester and die cast aluminum are close enough to permit replacement or intermixing of thermoset polyester materials with die cast aluminum. Thermoset polyester weighs 30 percent less than die cast aluminum.

COST STRUCTURES

Cost is an important factor underlying material and process selection. Cost prices, quantity projections, and tooling cost amoritization combine to affect this decision. A finished thermoset polyester part can cost up to 25% more than an unmachined aluminum die casting. By the time the die casting is finished, however, it can cost 10% to 60% more than the molding, depending on part complexity. Low shrink molding compounds, close parting line dimensional control, and molded-in inserts drastically reduce secondary labor and account for the difference in finished part prices. Table II compares these and other aspects of this process.

Tooling cost and lead time are roughly equal for either material. Both require hard steel tools for adequate mold life in production. For parts expected to have a life greater than 100,000 pieces, the economics of tooling expenditure changes in favor of thermoset polyester. Once production quantities exceed 100,000 pieces, new die cast tooling is required. Thermoset polyester tooling, on the other hand, can be used to produce up to 1,000,000 pieces, and has exceeded that quantity in injection applications.

The cost of hard tooling becomes a significant risk for an engineer when considering a change to thermoset polyester, particularly when the organization or the industry is not already using molded engineered plastics. Parts considered for casting can readily be prototyped in sand castings, at a fraction of the production tool cost. Until recently, the only alternatives for prototyping thermoset polyesters were soft steel or machined aluminum, both of which take as much as two-thirds of the time and cost of hard steel tools. Spray metal tooling has been developed, and can produce parts in a few weeks at a cost of 20% to 25% that of a hard tool. Special molding compounds are required, but the parts are a close facsimile of

a production molding. Kirksite tooling also offers an excellent alternative for various parts. Several tooling sources have developed the capability to design by computer and cut tooling from numerical control tapes generated by the computer. This approach can offer significant time savings particularly where compound profiles would require intricate model making. Program verification is done by cutting rigid foam blocks.

One aspect of the cost picture which is becoming extremely important today is the high energy consumption required to produce aluminum. In a report on lightweight materials for transportation, Owens Corning Fiberglas has developed energy needs for steel, aluminum, and glass reinforced polyester.(3) In it, a charge for aluminum production was estimated to be 45% virgin aluminum, 45% mill scrap, and 10% recycled scrap from the markets. At a 53% shipping rate, 85,900 BTU/lbs. were required. Conversely, a 30% glass, 30% polyester resin, and 40% filler mixture (thermoset polyester), at 80% molding efficiency, required only 28,400 BTU/lbs.

Aluminum production costs are directly tied to energy costs. On older production facilities, electrical energy costs represent 60% to 70% of ingot selling price. Even on the newest, most efficient facilities, electrical energy cost will represent 20% to 30% ingot prices. Given the expected increase in energy cost, tied to continued production capacity constraints, aluminum ingot prices are expected to increase a minimum of 10% per year. Although new production facilities are being added, aluminum availability is expected to remain tight over the next five years.

In 1976, vendor production of die cast aluminum parts was as much as 25% below production capacity. This surplus capacity, combined wtih increasing raw material cost has subjected vendor die casters to a considerable profit squeeze.(2)

Glass reinforcement energy consumption is due primarily to processing energy, but at a rate of less than half of aluminum ingot. As recently as 1977, glass plants were operating at capacity, resulting in a tight market. In early 1978, however, two glass plants were constructed, and have increased supply by about 20%.

A concern for potential users of plastic material is the petroleum base for resins and styrene, considering oil price increases in the last

six months. Most noteworthy is the price of styrene monomer which has jumped 80 percent between September, 1978, and May, 1979. A recent article on the polyestyrene market states that the Iranian oil cutoff deprived the industry of important chemical feedstocks. This sent commodity prices soaring, particularly in Europe, and forced Europeans to import benzene and styrene monomer from the U.S. at price levels lower than OPEC's. The result was a large outflow of U.S. produced monomer and polymer.(4)

In addition, if the current regulatory structure remains intact, domestic consumption of benzene will continue to shift to no-lead gasoline additives. At present, 40% of gas usage is unleaded and will grow to 80% in 1985. Petrochemical feedstocks comprise only 3% to 4% of an oil barrel, while gasoline comprises 46%. Thus, the politics of gasoline threaten to divert the supply of these aromatics away from petrochemical applications.(4)

Low profile resins, as well as chopped and roving glass reinforcements, have also been affected by energy constraints. They have had price increases in the neighborhood of 15 to 16% between November, 1978, and July, 1979. An additional 7% increase is expected by November, 1979.

What affect is all of this having on the cost of plastic materials, particularly thermoset polyester? Unreinforced thermoplastics such as polystyrene have had bulk material increases up to 70% and will probably be supplanted by materials such as polypropylene. Other instances are occurring where material changes are necessary to avoid the steep raw material price jumps seen in the last nine months. Glass reinforced thermoset polyester, on the other hand, contains approximately 30% styrenated resin, 40% to 60% fillers, and 15% to 30% glass. The increases to date have raised commercial grade black bulk molding compound costs only 5 to 6%.

What must also be considered is that material cost is variable from part to part, and in most cases, has less effect on price than press cycle time and labor content. Parts with more insert weight than material weight have had price increases less than 1%, while large parts with few inserts have had price increase of 5%.

MOLDING PROCESSES

The design engineer can select from three molding processes, each of which offers a variety of advantages. Compression molding, common for external parts, utilizes smaller press tonnage than closed mold processes, but can provide the highest degree of strength. Transfer molding, used for close tolerance parts, provides close parting line tolerances and a wide range of special molded-in inserts. Injection molding is ideal for high volume applications requiring close tolerances and no inserts. Table III outlines the characteristics of each process.

NEW PROGRAMS

In order to best illustrate the expanding capabilities of thermoset polyesters as a die casting replacement, recently tooled programs will be described. They include one external and two internal programs as follows:

THE HEWELETT PACKARD 250 WORKSTATION

The Hewlett Packard 250 is one of the first mini-computer workstations in the industry. The desktop represents the overall advancement of SMC/BMC as an alternate material for external parts, replacing sheet metal. It was designed and built to provide both beauty and strength. It weighs 38 lbs. (17.2 kg.), and measures approximately 61.5 in.(1560 mm) in length and 30.7 in. (780 mm) at its widest berth. The modified L-shaped design was used to provide easy access to the display screen, keyboard, and disc storage units. Radii and contours are abundant on the external surface to provide a modernistic look as shown in fugure 1.

The top is molded as a single piece, with a small beauty piece attached in assembly. The top rests on two sheet metal legs and the area around the keyboard sections has no direct support from below. Strength comes from the intricate network of ribbing and bosses shown in figure 2. The ribs are .250 inch thick and full depth because the unit is designed to be moved by lifting one end of the workstation and wheeling it from one location to another much like a wheelbarrow.

Twenty-three inserts are molded in for fastening purposes. Linear tolerances of $\pm$ .020 in. (.508 mm) over 40 in. (1016 mm) are held, as well

as ± .015 in. (.4 mm) across parting lines. A modified sheet molding compound is used to achieve the required UL rating for radiant panel per ASTNE-162 (flame spread index, 15 or less; distance of sustained flaming, 3 in. or less; dripping - none). Few secondary machining operations are required, except that the parts are patched, filled and sanded in preparation for painting.

The desk top for the H-P 250 is a perfect example of what can be done with SMC/BMC given that realistic approaches to design are taken and utilized. While this part offers some costs savings to Hewlett Packard, its major contribution to the entire 250 system is its stylish looks, strength, and weight. All three make this part an excellent application for SMC/BMC.

MEMOREX FLEXIBLE DISC DRIVE BASE

Memorex was the first manufacturer of flexible disc drive systems to replace a die cast aluminum drive base with thermoset polyester shown in figure 3. The application uses bulk molding compound (BMC) in a transfer mold. By utilizing a closed mold process, close tolerances are held, and secondary machining operations were eliminated.

The drive contains a disc rotation drive, a read-write head, and positioning motor, and electronic controls. The disc is driven from the rear of the drive through a belt and pulley system. The bearings for the spindle shaft have to be seated to minimize mis-alignment and movement. In order to do this, the bearing seats were molded by a pin planted in the mold. This allows the diameter to be adjusted to the size tolerance of ± .001 in. (.025 mm). The read-write heads are positioned by a stepper motor system which mounts on two parallel saddles - one for the stepper motor shaft, and one for the head carriage. The alignment between the mounts is ± .001 in. (.025 mm) to permit precise positioning of the head on the tracks of the disc. These areas were also planted in the mold to facilitate tune-in of size and location.

The entire part was designed for .125 in. (3.175 mm) wall thickness to minimize cure time and yet maintain rigidity. The six tabs on the edge of the part are guides for the disc cartridge. They are molded with

bypassing members which produce only a minimum of flash. Eleven inserts are molded into the top surface of the base, and six side inserts are post-mold installed. There are no-draft surfaces immediately around them to assure proper positioning when mounted.

Finally, the base conforms to a UL classification for radiant panel.

It represents a cost reduction of more than 50% when compared to a base made from die cast aluminum. Its success has greatly enhanced the argument for the replacement of aluminum die castings with thermoset polyester in business equipment.

TRAY-FRAME ASSEMBLY

The tray-frame assembly is also a breakthrough for transfer molded thermoset polyester as a replacement for die cast aluminum. It consists of three parts, which, when bolted together, become part of a business machine. The complex of bosses, ribs, and holes shown in figures 4 and 5 accomodates shafts between the frames and pulley drive system. The completed assembly, with all equipment installed, weighs 50 lbs. (22.7kgs), and pivots at two holes at the end of the side frames. The side frames are each 9 in. (228.6 mm) x 24 in. (609.6 mm).

Normally, these parts would have been tooled in die cast aluminum to facilitate the extensive machining of holes and datum surfaces. The design engineers, in this case, wanted to fully evaluate other processes in an attempt at reducing cost. After looking at a considerable number of processes, they selected outsert molding and reinforced thermoset polyester molding since they met dimensional and strength constraints. The primary criteria for the program was to obtain parts which would require little or no machining. As the designed progressed, however, the complexity of the parts surpassed the capabilities and cost effectiveness of oursert molding.

The cost of tooling and parts supported the technical requirements as shown below. The cost of transfer molded BMC is equal to unity, and the comparative cost of other processes are multiples of one.

	Tooling	Parts
Die Cast Aluminum	1.2	2.0
Thermoset Molded BMC	1.0	1.0
Outsert Molding	1.3	1.75

The tooling costs for die cast aluminum and reinforced thermoset polyester are typically close to each other, while outsert prices are higher because a stamping die and a mold are needed. The part costs for die cast aluminum reflect the extensive machining required, while outsert costs are higher because they require stamping and then molding.

The initial material selection was sheet molding compound (SMC) because of its strength. After review of the tolerances across parting lines, and the need for special insert pins, 15% glass reinforced bulk molding compound (BMC) was selected for transfer molding. Stress calculations confirmed that BMC would provide adequate strength and rigidity. The low shrink, low profile characteristics of BMC permitted molding of diametral tolerances of .001 in. (.025 mm), and positional tolerances of .008 in (.178 mm) over as much as 15 inches (381 mm).

Operational tests have confirmed that the molded assembly is strong and rigid enough for the application. The material has provided and unexpected benefit in the form of a significant reduction in noise output, since thermoset polyester dampens rather than resonates the vibration set up by shaft and pulley rotation.

A major factor in the success of this program was frequent communication between the design engineers and the molder. At the outset, the application was discussed at length to inform the tool designers of design parameters. As a result, design concessions were made before the mold was built to optimize part moldability. In addition, five revisions were made during the mold build, but contingency planning and coordination permitted a majority of the changes to be made without delaying mold delivery.

CONCLUSION

Thermoset polyesters have proven their reliability as a strong, lightweight, stable material. They offer excellent performance criteria at substantial cost savings. These two factors give the engineer the flexibility needed to utilize thermoset polyester as a realistic alternative to aluminum die castings. The recent success of thermoset polyester programs further indicate that the custom molders of thermoset polyester are prepared for continued growth into new and diversified business equipment applications.

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1. Design Options for Business Machine Housings.........*Plastic Design Forum*, Sept/Oct, 1978.

2. *Market Research Report - Fiberglas/Plastic Compound Opportunity in the Die Cast Aluminum Industry*.....................Owens Corning Fiberglas.

3. *Fiberglas/Plastics and the Energy Challenge*...........Owens Corning Fiberglas.

4. The Polystyrene Picture.....*Plastics World*, June, 1979

TABLE I - MATERIAL COMPARISON

	15% Glass BMC (1)	25% Glass SMC (2)	Aluminum Alloy #380 (3)
Tensile Strength, PSI x 10^3	3 - 5	7 - 10	48
Compressive Strength, PSI x 10^3	20	20	24
Flexural (Yield) Strength, PSI x 10^3	16 - 20	18 - 25	(23)
Modulus of Elasticity in Flexure, PSI x 10^6	1.2 - 1.5	1.5 - 2.0	10.3
Impact Strength, Izod Notched, Ft-Lb/in.	6 - 10	9 - 12	5 - 7 (4)
Heat Resistance, ^{o}F Continuous	250	250	500
Flammability, UL Where Applies	94V-0 RP-15(2)	94V-0	N.A.
Thermal Coeff. of Expansion, in/in -^{o}c x 10^{-5}	1.5	1.5	2.1
Specific Gravity	1.94	1.90	2.72

(1) ROSITE 3550C

(2) ROSITE 3550FM

(3) Alcoa Aluminum Handbook

(4) Experiemental Data

Values shown are based upon standard tests on specific configurations and are offered as a guide. No other guarantee is implied. Characteristics are subject to variation as applied to specific part design.

TABLE II - PROCESS COMPARISON

	15% Glass BMC (1)	25% Glass SMC (2)	Aluminum Alloy #380
Feature Size Control	Molded	Molded	Machined
Feature Location Control	Molded	Molded	Machined
Datum Surfaces	Molded	Molded	Machined
Counter Bores	Molded	Molded	Machined
Shafts, Pins	Molded-In Inserts	Molded-In Inserts	Machined
Tapped Areas	Molded-In Inserts or Post Molded	Molded-In Inserts or Post Molded	Machined
Shrinkage, Minimum	$\pm$ .0005 in/in	$\pm$ .001 in/in	$\pm$ .002 in/in
Draft/Side, Minimum	1^{o}*	1^{o}*	3^{o}

* Localized no draft areas possible

(1) ROSITE 3550C

(2) ROSITE 3550FM

TABLE III PROCESS CHARACTERISTICS

All processes can be used for prototypes, except transfer substituted for injection. All processes permit multiple cavity molds. Transfer and injection molds can be designed for family production.

COMPRESSION

- Can use sheet or bulk molding compound
- Mold closes on material
- High strength/less material flow and random glass orientation
- $\pm$ .015 in. (.381 mm) parting line tolerance / heavy flash in openings and on seal areas
- Inserts molded-in

INJECTION/TRANSFER

- Can use bulk molding compound only*
- Mold closes dry and material shot after closed
- Lower strength/material flows across entire part with glass orientation in flow direction
- $\pm$ .003 in. (.076 mm) parting line tolerance/light flash in openings
- Inserts molded-in - transfer only

* Sheet Molding Compound can be preloaded into transfer molds for localized high strength.

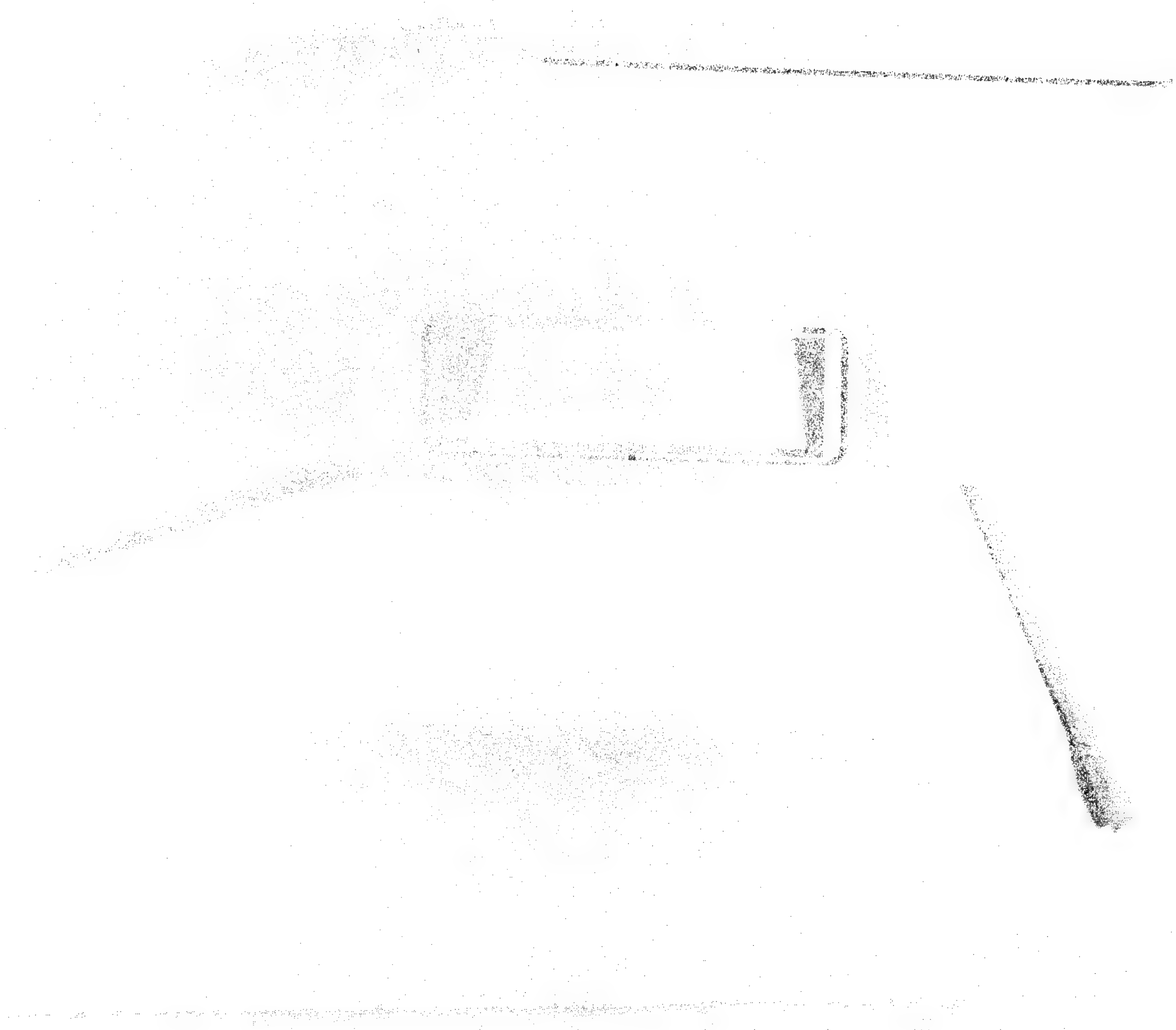


Figure 1. Desktop for Computer Work Station - modified L-shaped design provides modernistic look.

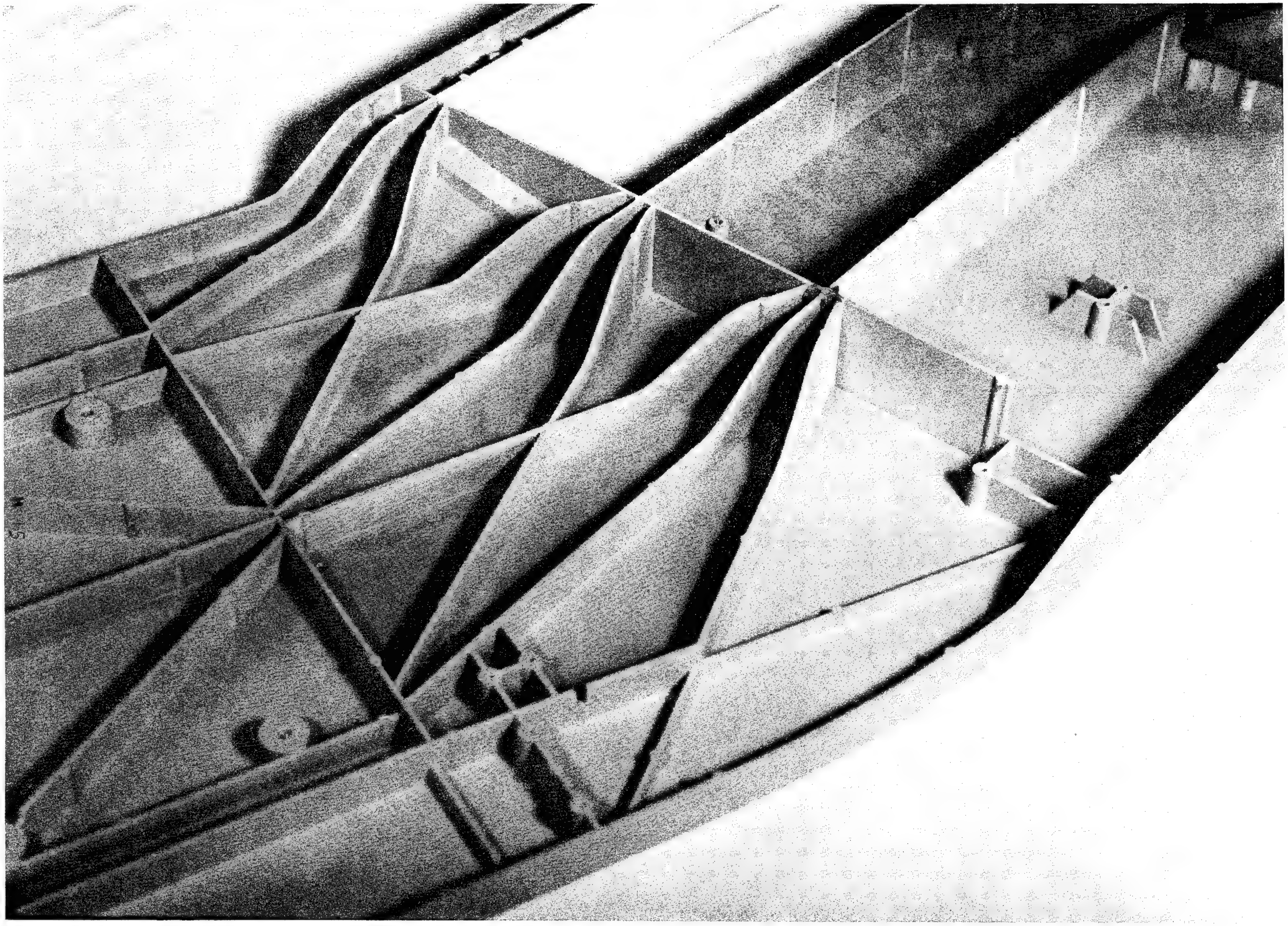


Figure 2. Underside of Desktop shows ribs and bosses for strengthening.

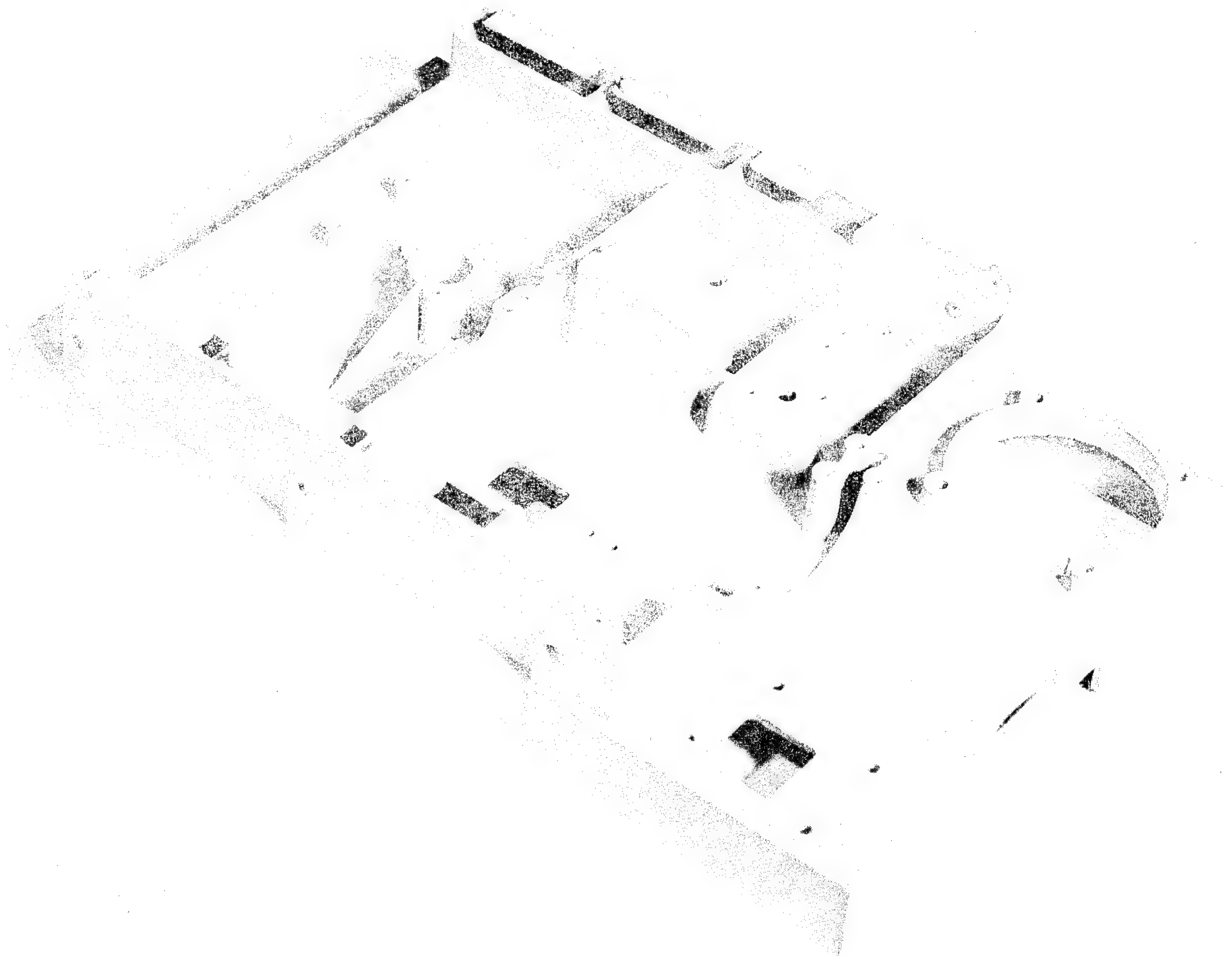


Figure 3. Flexible disc drive base molded with BMC.

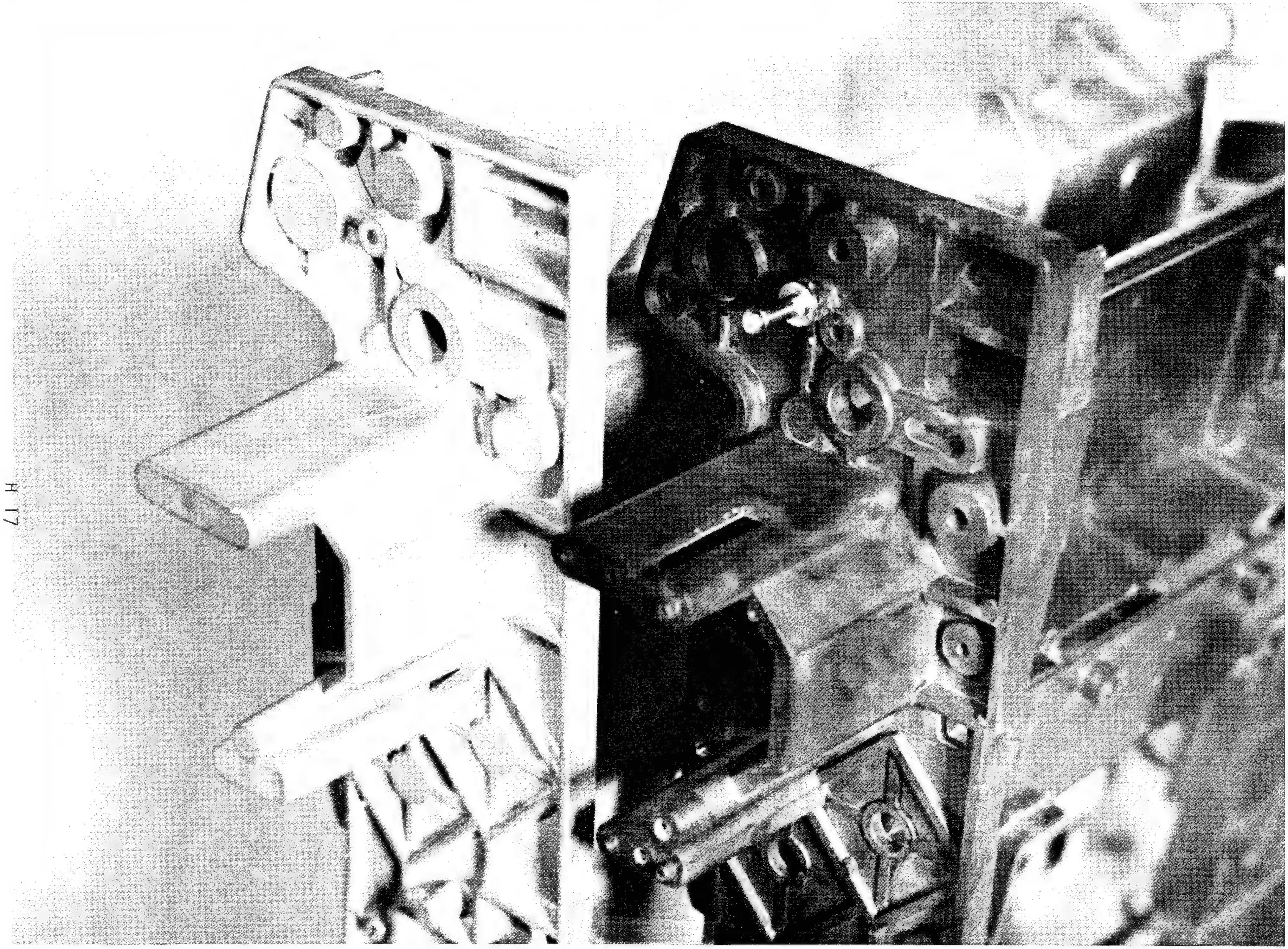


Figure 4. Detail of business machine frame member of aluminum sand casting compared with the replacement molded of BMC.

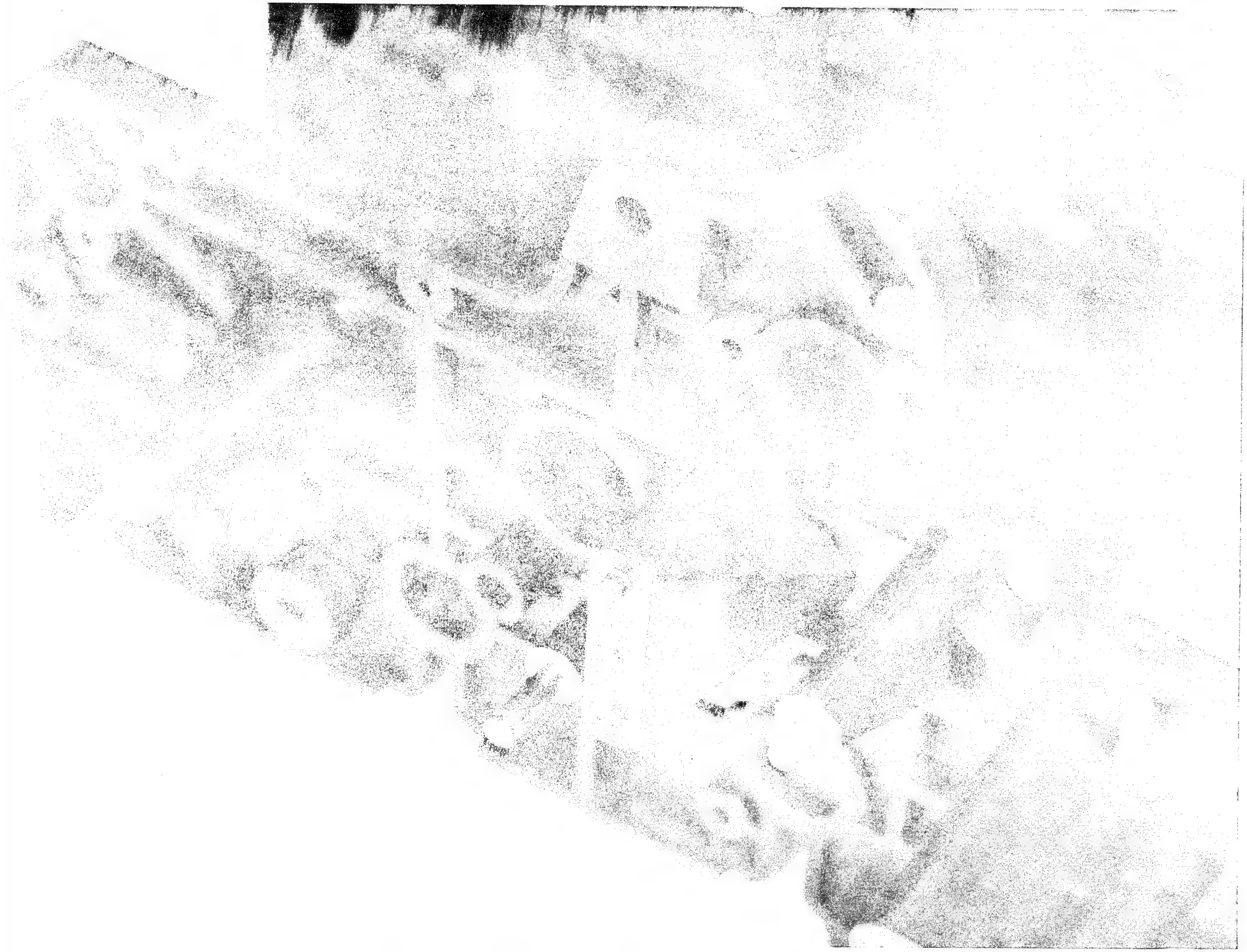


Figure 5. Detail of molded-in inserts - pins and tapped holes - ribs and bosses.

"HOW TO REDUCE COSTS AND IMPROVE QUALITY FOR SECONDARY FINISHING"

Paul Burton
Leon Plastics Co.
Grand Rapids, Mich.

This paper was not available at the time of printing.

SPE RETEC ROCHESTER, NEW YORK

SEPTEMBER 20, 1979

" AN ECONOMICAL APPROACH TO FIBERGLASS

REINFORCED INJECTION MOLDED PARTS"

Joseph Sutej
Group Leader
Styrene Polymers
Arco/Polymers, Inc.

INTRODUCTION

Approximately 275 million pounds of injection molded fiberglass reinforced thermoplastics are consumed in the U.S. annually. The majority of these materials are resins which are sold as pellets containing glass strands encapsulated in the plastic pellets. However, a considerable quantity of glass reinforced thermoplastics are molded, particularly in the automotive industry, as mixtures of plastic particles and chopped fiberglass strands. This approach offers advantages over precompounded materials, primarily enhanced physical properties and reduced cost.

Though this approach to molding glass reinforced thermoplastics is new to business machine manufacturers, it has been widely used for several years in the automotive industry, and is being used by more molders each year. There are two options available in using these "dry blends": Purchasing a pre-blended product, or purchasing chopped strand fiberglass and resin then blending in-house. In-house blending offers maximum efficiency, and facilitates utilization of regrinds. In this paper we will discuss blending and handling of dry blends, selection of fiberglass type, and properties.

INTRODUCTION (Continued)

Special handling equipment is necessary when using dry blends. The transfer systems used should be gentle and minimize mechanical abuse of the fiberglass chopped strands. Excessive mechanical abuse will result in filamentation of the chopped strand bundles. Filamentation of fiberglass bundles can reduce dry flow properties of the mixtures resulting in bridging problems in machine hoppers. Filamentation can also generate dust which can get in the air and cause numerous nuisance problems. However, when handled properly these mixtures are trouble free, and the advantages of high aspect ratio on physical properties of the molded parts can be economically achieved.

Dry blend products are typically supplied in bottom dump cartons or metal bins. A molder empties these containers by gravity into either the machine hopper, if there is sufficient overhead space, or into a receiving bin beside the molding machine where the mixture is transferred to a closed top hopper using a gentle auger conveyor. Using this containerized concept minimizes problems associated with fiberglass dusting since the systems are closed.

MISCONCEPTIONS

The proponenents of precompounded materials typically cite numerous unfounded objections to the use of dry blended fiberglass reinforced products.

MISCONCEPTIONS (continued)

I will address the most frequently mentioned potential problem areas

- The theory behind the excessive wear argument is that the fiberglass strands added at the feed section of the molding machine wear both the barrel and screw through abrasion. If the glass were encapsulated in a plastic pellet, the glass could not come in contact with the machine before a lubricating layer of melted polymer were first formed. Sounds reasonable. However, the data do not support the theory.(1) Most of the wear occurs long after the polymer has melted, forward of the feed zone, and in an area which was supposedly protected by a lubricating layer of polymer melt.
- Another popular anti-dry blend theory is that dry blends cause abnormal mold wear due to abrasion and corrosion. Abrasion in the mold does occur, in spite of the lubricating action of the polymer melt, but at that stage of the process the glass does not know whether it arrived at the machine as a precompound or a dry blend. All the glass is encapsulated by polymer melt. Why would one system abrade the mold more than another? In fact, there is no significant difference in abrasion of the tools.

MISCONCEPTIONS (Continued)

As for corrosion of molds, this is a consequence of improper glass selection and can occur with both systems. To understand this phenomenon one needs to understand the structure of a piece of chopped strand. A piece of chopped strand fiberglass is a bundle of 200-800 filaments of surface treated glass held together by a binding resin. The choice of binding resin is one of the primary differences among the various grades of chopped strand fiberglass. Polymers selected as binding resins include polyesters, EVA's polyurethanes, and epoxies. The resins impart differences in handling characteristics, ease of dispersion, and resin compatibility.

Unfortunately, not all binding resins possess sufficient thermal stability to be processed at temperatures of 500°F or higher as required with some materials and applications. We have demonstrated that the binders of some of the more popular glasses, which also have some of the best dry handling properties, will break down to yield acid when when subjected to 500°F in molding. This evidence surprised even the fiber glass supplier who believed that the EVA used was stable, based on Thermal Gravimetric Analyses (TGA) data. Unfortunately, TGA data were generated using a rapid heating and not heat soaking. The TGA tests did not simulate the time-temperature profile of injection molding.

MISCONCEPTIONS (Continued)

- Poor dry flow properties, i.e., bridging in the machine hoppers, can be eliminated by the addition of additives to the surface of the plastic granules by the resin supplier. Subsequent dry flow problems are caused by improper handling of the dry blends, either by the blend supplier or the molder. These problems are a result of filamentation of the chopped strands evidenced by patches, mats, lumps, or fuzz balls of glass which inhibit dry flow. With proper additive selection and addition, and proper in-plant handling of the blends by the molder, dry flow problems are eliminated.

- A major concern of all of us is the safety of our employees. Many believe that fiberglass dust in the air and dry blends are synonymous. Dusting can be controlled with proper handling, and the use of closed systems. There are molders running 5-10 million pounds of dry blends in large, unionized, safety conscious plants, without dusting problems. The secret is proper handling equipment and proper safety attitude by those in the plant.

- Some believe that dry blends segregate in shipment. ARCO Polymers and others have run many transportation tests evaluating numerous plastic granule geometries to determine whether separation is a potential problem. Though ARCO Polymers primarily manufactures coarse ground pellets to produce dry blends, data show these as well as spherical pellets from underwater pelletizers, are satisfactory in dry blends with glass fibers.

HANDLING OF DRY BLENDS

The solution to many of these problems is proper handling. To show that such handling systems need not be expensive, let us examine the cost/performance of a properly engineered system.

The product is purchased as a dry blend at a price approximately 8¢-12¢ below the cost of a precompounded product. The material is packaged in 1,000 pound bottom dump cartons or 3,000 pound closed metal bins. To use the material, the closed containers are transported to the molding machine by lift truck and placed on top of a receiving bin where they are emptied by gravity into the bin. Depending on headroom available over the molding machine, the receiving bins are either on the hopper, or on the floor beside the machine. If the receiving bins are on the floor the material is transferred up to the closed hopper by a gentle auger from the bottom discharge of the bins.

The system is quite simple and inexpensive. It consists of

Receiving Bin

Auger Drive

Transfer Auger

Level Sensor For Hopper

Sequencing Control

Estimated cost is $2,000/installation

HANDLING OF DRY BLENDS (Continued)

This system will be paid for after running 17 M - 25 M pounds of glass blends through the machine. If bottom dump cartons or bins can be placed directly above the machine hopper the cost effectiveness is even better.

ARCO Polymers R&D have evaluated a number of systems to transfer dry blends. Our recommendations are these:

- Most grades of chopped strand fiberglass lack sufficient toughness in the binding resin to withstand conventional air transfer systems normally used in plastic molding plants. Filamentation will usually cause chronic problems at the molding machine. We do not recommend air transfer systems.
- Helical coils inside flexible plastic tubes often work. However, variations in design of the coils (circular cross-section versus flat cross-section) has created a mixed bag of results . These are generally operated at too high of a speed to be trouble free. Some designs, particularly those with circular cross-sections, tend to force the blends toward the walls of the tubes, and with all but a few glass types, grind the chopped strands sufficiently to cause filamentation. If these are used they should be operated at slow speeds and glass selection is more critical.
- Bucket transfer systems and belt systems work , but these are not closed systems , and dusting is a potential problem. We prefer closed systems.

HANDLING OF DRY BLENDS (Continued)

- Conventional augers operated at low speeds are best. These can move 1,000 pounds/hour at these speeds. They are adequate even for most low pressure structural foam machines.

For those who prefer to blend in-house or cannot purchase "dry blends" from their suppliers, in-house blending is a relatively simple process. However, the choice of equipment must be made keeping in mind the necessity to be gentle with the glass fibers. Hopper metering/blending systems are, in general, too rough for chopped strand fiberglass. We recommend low speed (40 rpm) paddle type and ribbon blenders used in a batch process. Blending times are very short. A typical cycle is:

- Load chopped strand fiberglass
- Load the thermoplastic and regrind
- Blend for 30-45 seconds
- Discharge completely in 15 seconds

The additive systems are necessary to maintain free flow properties and are generally added to the resin by the supplier. These can be added at the ribbon blender but then the glass must be added last after the additives have been blended with the resin. These systems must be developed specifically for different polymers and glasses. Typical additive systems include antistats, and common lubricants such as metal stearates, and long chain amides. Perhaps your polymer or fiberglass suppliers could assist in this additive selection.

GLASS SELECTION

Selection of the best grade of fiberglass is much more involved. You need a product which has good strand integrity, not only at room temperature, but often at low temperatures. Low temperature tests must be run to simulate winter mixing conditions where materials are brought into the mixing area from trucks or silos when the outside temperatures are quite low. Even if your fiberglass is stored in a heated warehouse, the majority of your mixture is plastic brought in from a silo, possibly a below 0°F environment. The moderately warm fiberglass will cool rapidly in you blender, and the binding resin might embrittle slightly. Filamentation at low temperatures must be investigated.

We have developed relatively simple tests to determine the potential of various grades of chopped strand fiberglass for use in dry blends. Bundle integrity is measured by a simple shaker test at room temperature and at 0°C. In this test 50 grams of the mixture of plastic granules and fiberglass chopped strands are added to a 500 ml Erlenmeyer flask and shaken on a wrist action shaker for 16 hours, then visually examined for patches of fiberglass, balling, and dust generation. Many candidate glasses are eliminated at this point. Those mixtures with minimum filamentation are shaken an additional 16 hours to further differentiate strand integrity. If your dry blends will be exposed to low temperature handling these tests should be conducted at low temperature also.

GLASS SELECTION (Continued)

Dry flow properties of dry blends are measured using a simple funnel discharge test. A large funnel, approximately 6 inches at the top with a one inch opening at the base is used. It is filled to capacity with the blend to be checked while the discharge end is closed with a flat plate. The plate is removed and the discharge time is measured. If the material stops flowing before the funnel is emptied the material will not feed a molding machine. Discharge times of less than 15 seconds are good. If a blend discharges completely but requires more than 15 seconds, it will most likely not feed an injection molding machine. The performance of mixtures in this test is affected by additive systems, and this test is useful in screening additive systems for specific glass/plastic combinations.

Corrosivity of the degradation products is more complex. In addition to corrosive degradation of the binding resin on the glass, the primary polymers, flow additives, colorants, and base resins used with color concentrates need to be evaluated. Hygroscopic resins can also give off water which, generally, is only mildly corrosive when compared to corrosive degradation products, but water can cloud results.

There are a number of corrosion tests reported in the literature. A test reported by Calloway, Morrison, and Williams[(2)] of Eastman Kodak is especially useful, however, it is sensitive to water. But relative to other corrosive substances potentially present in plastic/fiberglass systems, water corrosion is readily distinguished from that of more corrosive substances.

GLASS SELECTION (Continued)

In this test, samples are heated in a flask under vacuum and the vapors generated are collected in a cold trap. Metal bars of the particlular metal of interest are suspended in the collection flask for 24 hours then evaluated qualitatively. Each component of a system must be evaluated separately, and then in combination to determine if any synergistic effects result. Table I gives the dry flow, reinforcing, and corrosive properties of several grades of fiberglass studied in our labroatory.

PHYSICAL PROPERTIES

As mentioned previously one of the primary advantages of fiberglass dry blends is improved physical properties. This property advantage is most dramatic in notched Izod impact strength.[3] DYLARK® 238 heat resistant copolymer, a styrene maleic anhydride copolymer manufactured by ARCO Polymers, Inc. is used widely in the automotive industry as a dry blend with 20% 1/4-inch chopped strand fiberglass. As a dry blend this product has a notched Izod impact strength of approximately 2.5 - 3.0 ft. lbs./in. of notch. A precompound of DYLARK 238 with 20% fiberglass typically exhibits 1.0 - 2.0 ft. lbs./in. of notch. Other properties such as tensile and flexural properties for dry blends and precompounded products are very similar, but dry blends generally exhibit higher values.

These property advantages are due to the molded dry blends having longer glass fiber length than precompounded products. Fiberglass length in injection molded parts produced from dry blends typically range from 0.8 mm - 6.0 mm. Injection molded

PHYSICAL PROPERTIES (Continued)

parts molded from precompounded materials are typically 0.3 mm - 2.8 mm. These longer fibers are a result of the fiberglass having been sheared only when being molded, while precompounding shears the glass in the compounding extruder and in the molding machine.

Table II demonstrates the properties of DYLARK 238 reinforced with 20% 1/4-inch chopped strand fiberglass as a molded dry blend and a molded precompound. Table III presents similar data for DYLARK 250 reinforced with 20% fiberglass as a dry blend and a precompounded product.

SUMMARY

We believe the dry blends of 1/4-inch chopped strands offer an economical alternative to precompounded fiberglass reinforced products. With proper handling techniques these will not cause plant nightmares of fiberglass dust in the air, and bridging in the machine hoppers.

NOTE:

®DYLARK - ARCO Polymers Registered Trademark for Heat Resistant Styrene Copolymers

REFERENCES

Calloway, G.P., E. D. Morrison, and R. F. Williams. SPE Journal, 28, 60 (August, 1972) "Do Corroded Molds Get Down!"

Francis, P.S.. "Glass Reinforced Styrene-Maleic Anhydride Copolymers," reprint of article presented at the 34th Annual Technical Conference, The Society of the Plastics Industry, 1979, Section 10-F, pp. 1-5

Olsted, B.A. SPE Journal, 26 42 (1970), "How Glass-Fiber Fillers Affect Injection Machine"

Table I

Reinforcing Properties of Various Non-Corroding Fiberglass in Dylark 238 #35

	OCF [3] (885) (Corrosive	CTD [1] (927)	CTD [1] (952)	PPG [2] (3197)	PPG [2] (3535)	OCF [3] (419)	OCF [3] (832)
Tensile Strength, psi	12,400	13,800	14,300	14,200	13,700	10,600	11,500
Elongation, %	1.6	1.8	1.8	1.8	1.8	1.4	1.5
Flexural Elastic Modulus, psi	893,000	936,000	909,000	962,000	924,000	844,000	825,000
Flexural Strength, psi	20,100	22,000	18,400	22,600	21,500	19,000	18,600
Izod, Notched, ft. lbs./in.	2.6	2.4	2.7	2.3	2.9	3.1	2.9
Unnotched, ft. lbs./in.	4.7	6.7	8.2	6.3	6.5	5.3	5.2
DTUL, °F	232.5	234.8	238	232.0	235	234	232.3
Specific Gravity	1.19	1.24	1.25	1.23	1.20	1.25	1.21
% Fiberglass	20.7	23.4	22.2	16.8	20.2	19.2	18.5
Comments	PVOAc Binder (Corrosive), Strand Integrity O.K., Good Dry Flow	Unknown Binder, Strand Integrity O.K., Poor Dry Flow	Poly-urethane Binder, Strand Integrity O.K., Poor Dry Flow	Poly-ester Binder, Strand Integrity O.K., Poor Dry Flow	Poly-urethane Binder, Strand Integrity O.K., Poor Dry Flow	Epoxy Binder, Strand Integrity O.K., Good Dry Flow	Poly-ester Binder, Strand Integrity O.K., Good Dry Flow

1 - Certainteed Corporation
2 - PPG Industries
3 - Owens Corning Fiberglass Corporation

Table II

DYLARK Heat Resistant Copolymer (Dry Blend)

Versus

DYLARK 232 + 20% FG (precompound)

	DYLARK 232 (Dry Blend)	Dylark 232 (Precompounded)
Tensile Strength, psi	14,000	11,600
Elongation, %	1.4	1.3
Flexural Strength, psi	19,000	17,300
Flexural Modulus, psi	1,040,000	990,000
DTUL, 1/8" bar, °F unannealed, 264 psi	233	233
Izod Impact, ft. lbs./inch	2.8	1.0
Gardner Impact, in./lbs.	14	5

Advantages of Dry Blend Versus Precompound

1. Higher tensile and flexural properties
2. Higher impact properties

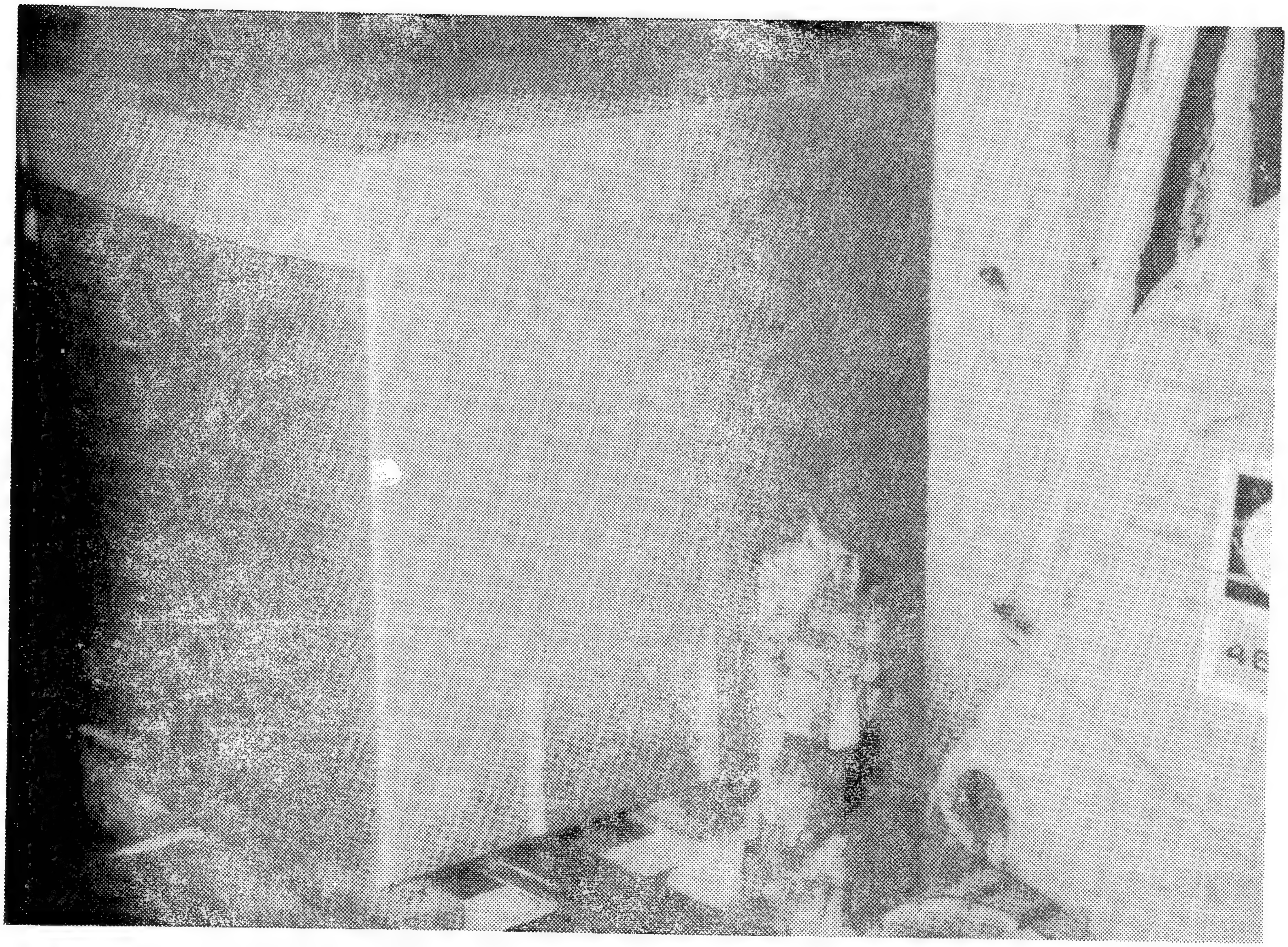
Table III

DYLARK Heat Resistant Copolymer (DRY BLEND)

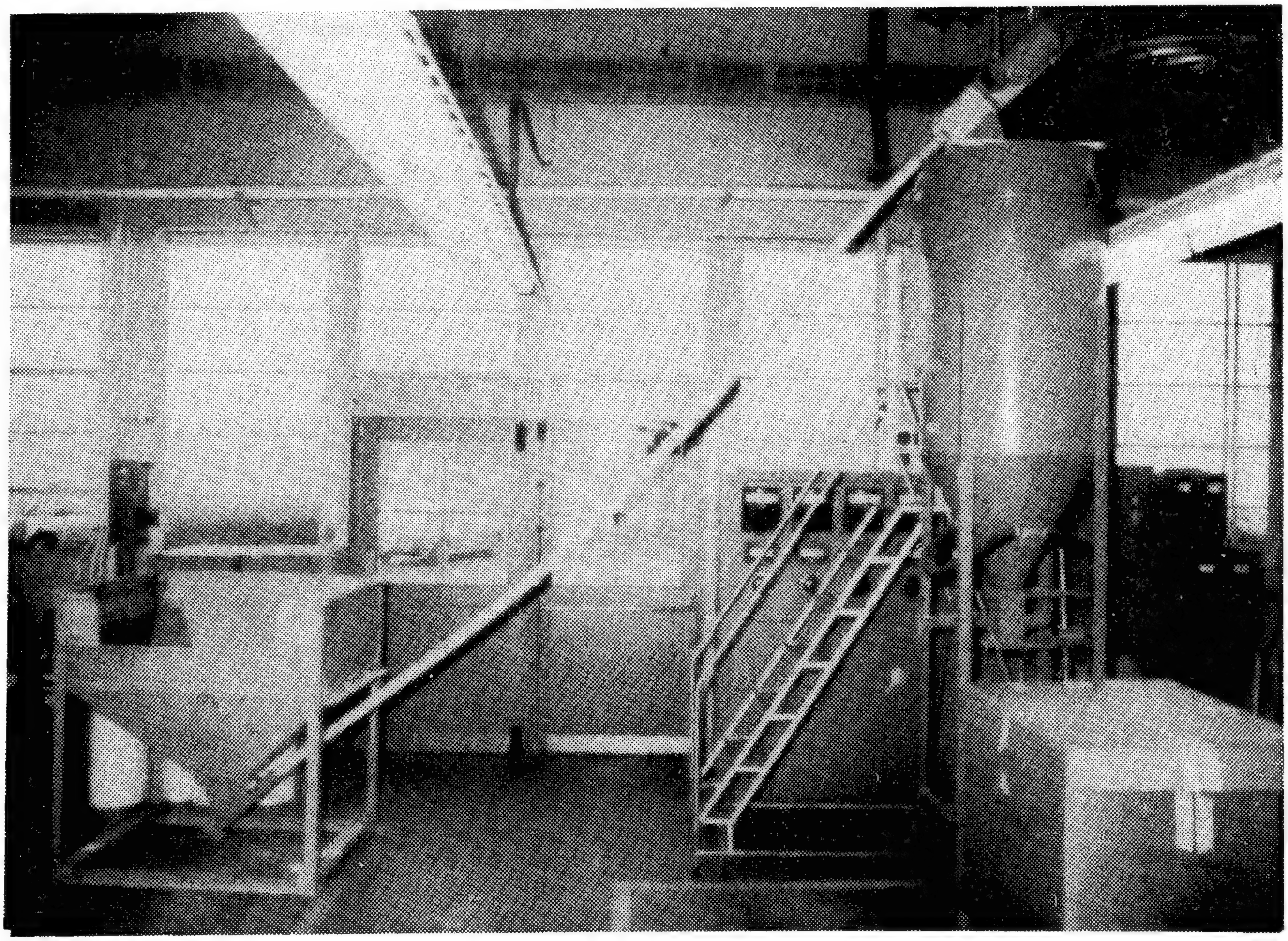
VERSUS

DYLARK 250 + 20% FG (precompounded)

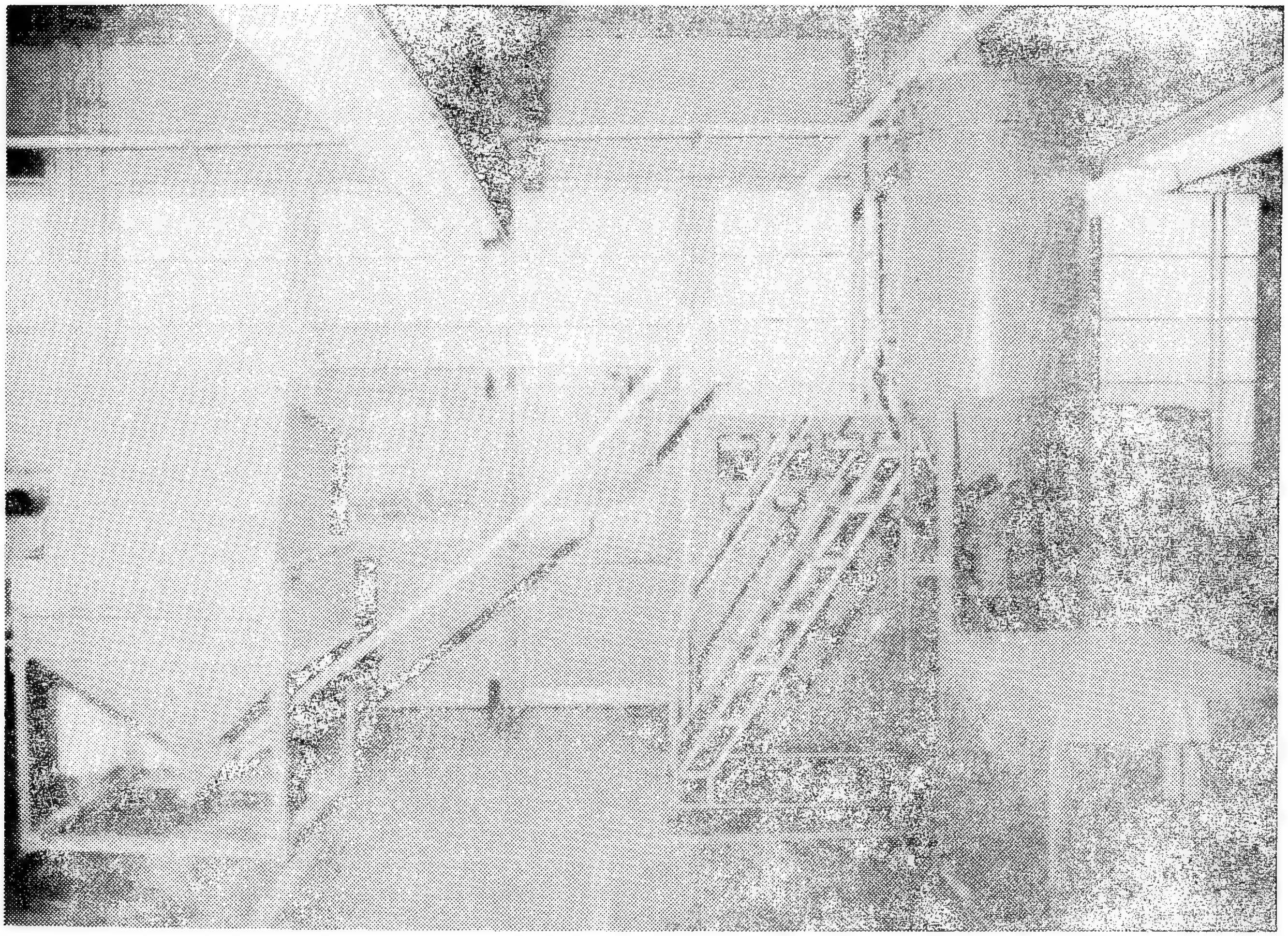
	Dry Blend DYLARK 250 F-20	Precompound
Tensile Strength, psi	11,700	9200
Elongation, %	1.7	2.5
Flexural Strength, psi	17,800	14,300
Flexural Modulus, psi	858,000	620,000
DTUL, 1/8" Specimen, °F Unannealed 264 psi	229	228
Izod Impact ft. lbs./inch notched	2.7	1.6
unnotched	7.7	6.5
F.W.I., inch lbs.	9	3.4



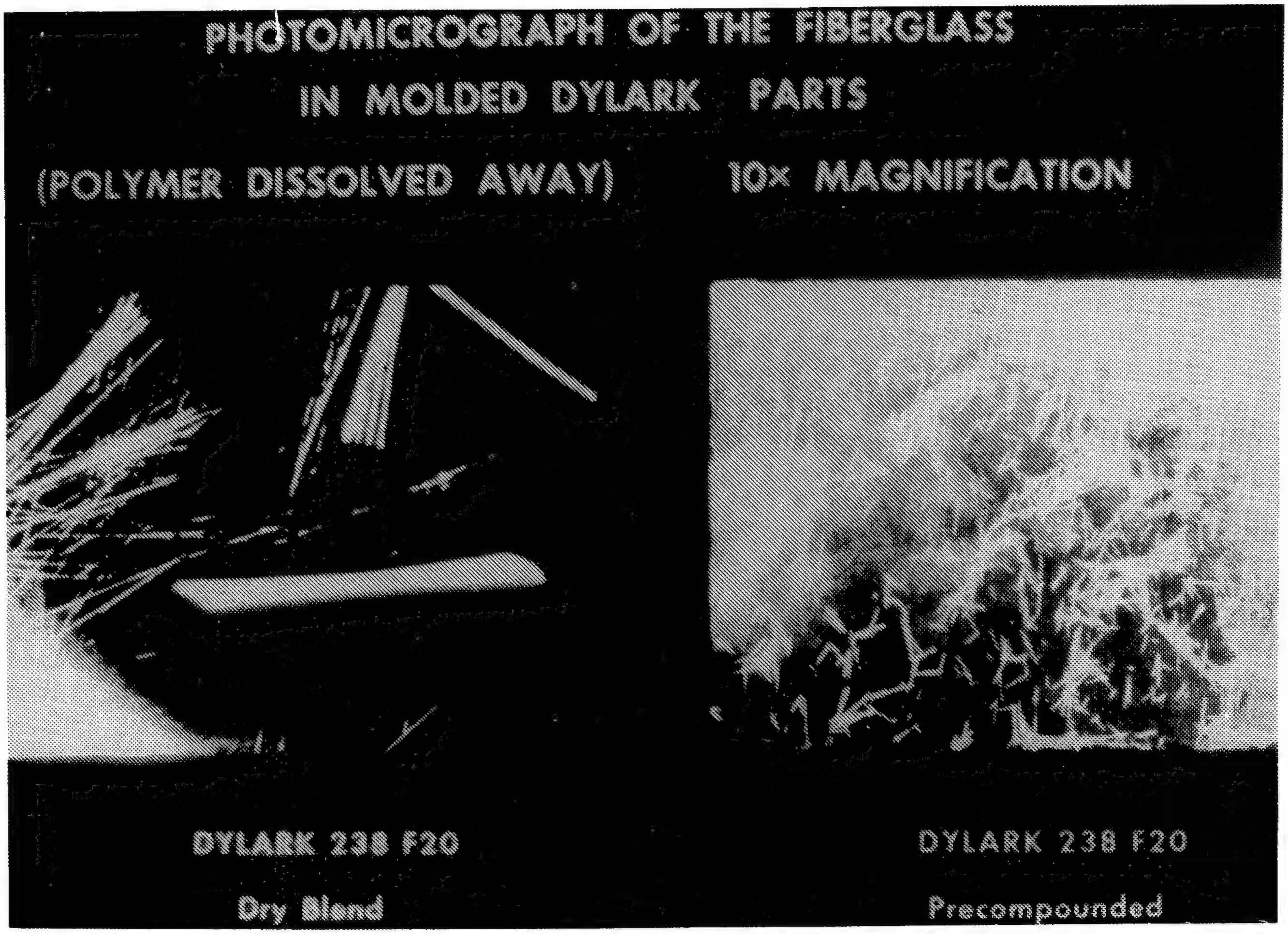
BOTTOM DUMP CARTON SHOWING POSITION OF FORKLIFT



BIN WITH AUGER TRANSFER SYSTEM TO CLOSED HOPPER



BOTTOM DUMP CARTON POSITIONED IN RECEIVING BIN



FIBERGLASS LENGTH: DRY BLEND VERSUS PRECOMPOUND

The Effects of Processing Parameters on the Physical Properties of N190-N225 NORYL Resins

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Introduction

It is the primary purpose of this paper to acquaint molders and designers with information that will help them maximize final molded part characteristics of two Noryl high performance resins. Specifically, melt temperature, mold temperature, injection pressure and regrind are examined for their effects on physical properties, on knit line integrity, and on flow length.

The General Electric Company's NORYL Products Department created Noryl N190 and N225, high performance resins, as a result of demands placed upon the business machines, water handling, TV and electronics, and appliance industries. Each of these industries required certain specifications that only a high performance engineering thermoplastic resin could provided. Detailed information on both of these high performance Noryl resins is included in later sections of this paper.

Special Properties Required by the Selected Industries

The selected industries—water handling, business machines, TV and electronics, and appliances—demand exceptionally high performance from their engineering thermoplastics. To meet these unique yet necessary specifications, Noryl N190 and N225 resins were developed.

In business machine applications, conventional engineering plastics could not provide the tensile strength, flexural modulus and impact required, nor the cost saving advantage of a thin walled section. This is particularly true for cases and cabinets. Additionally, in many attempts to replace heavy die cast metal parts with plastic, the strength limitations imposed by molded plastics, often proved it to be impracticable.

For the TV and electronics industries, plastic parts for use in high heat areas have always been a compromise. The decorative parts, such as cases and grilles presented a designer with few alternatives to wood laminate or metal. A high strength engineering thermoplastic resin with appropriate flammability ratings and high heat properties that could be decorated by conventional methods, was clearly a design goal. And, if the plastic was capable of providing an economical advantage of thinner wall sections its value would be even higher.

The requirements for appliances such as vacuum cleaners, coffee makers and hair dryers, are high impact strength, high heat tolerance, low water absorption, and suitable flammability ratings.

In the area of water handling devices, an injection molded plastic with superior hydrolytic stability is a must for continued fit and function under hot and cold water cycling and autoclavable parts.

Therefore, Noryl N190 and N225 high performance resins were developed.

Performance Characteristics of Noryl N190 and N225

Table 1 is a chart of various properties of N190 and N225 resins. Note the high values of the materials for heat deflection, Izod Impact and tensile strength. Note also the excellent hydrolytic stability; the lowest of any engineering thermoplastic. Both resins meet U.L. 94 V-0 requirements and offer a specific gravity well below that of other thermoplastics carrying similar ratings. Further information on physical property characteristics materials at various processing conditions is contained in another section of this paper.

Table 1

N190/N225 Physical Properties

Property	NORYL N190	NORYL N225
Heat Deflection Temperature @ 264 psi	190° F	225° F
Izod Impact Strength @ 73° F	7.0	6.0
Izod Impact Strength @ -40° F	3.0	2.5
U.L. 94*	V-0	V-0
Tensile Strength, psi @ 73° F	7,000	8,000
Water Absorption, 24 Hrs., 73° F, %	.07	.066
Specific Gravity	1.08	1.09

*This rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.

Effects of Processing Conditions on Various Properties

It is well known that varying the processing temperature, mold temperature, number of regrinds, and injection pressure will have an effect on the performance under load and physical properties of molded parts. The studies listed below define and discuss these interrelating variables for both N190 and N225 resins.

The impact of up to 5 complete regrinds on various physical properties.

The degradation of physical properties at the upper limits of processing (melt) temperatures.

The effect of processing temperature on knit line properties.

The relationship between mold temperature and finished part physical properties.

The relationship between flow length and processing temperature for constant injection pressure and mold temperature.

Regrind Effects

Figures 1 through 6 illustrate the effects of repeated regrinds, up to 5, on various physical properties for N190 and N225 resins.

Note that Flexural Strength (Figure 1), % Elongation (Figure 2), and Tensile Strength (Figure 3) show no effect at all for 5 regrinds.

Figure 1

Flexural Strength vs. Regrind

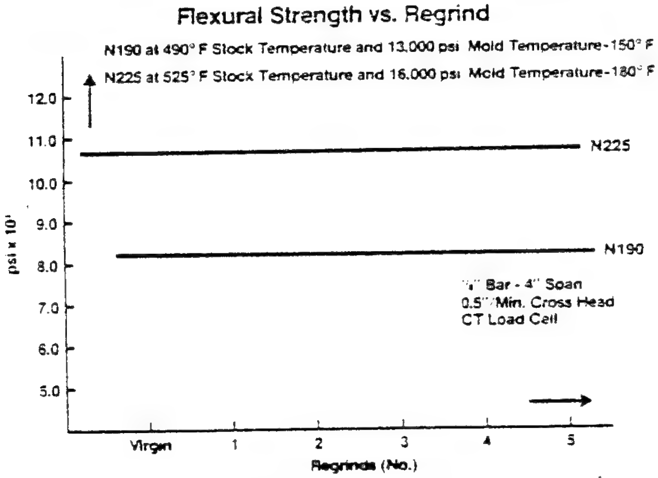


Figure 2

% Elongation vs. Regrind

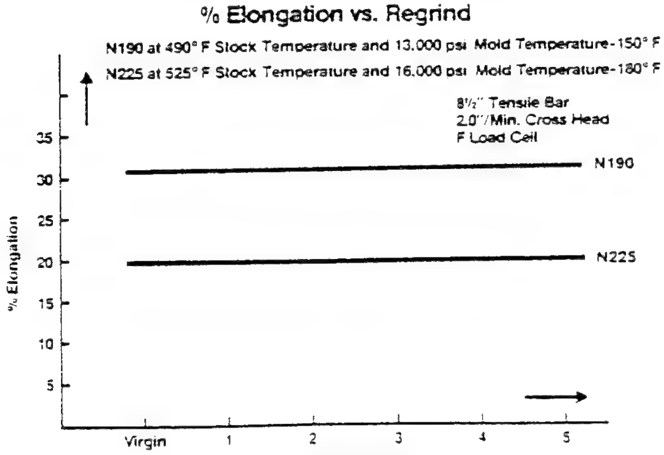
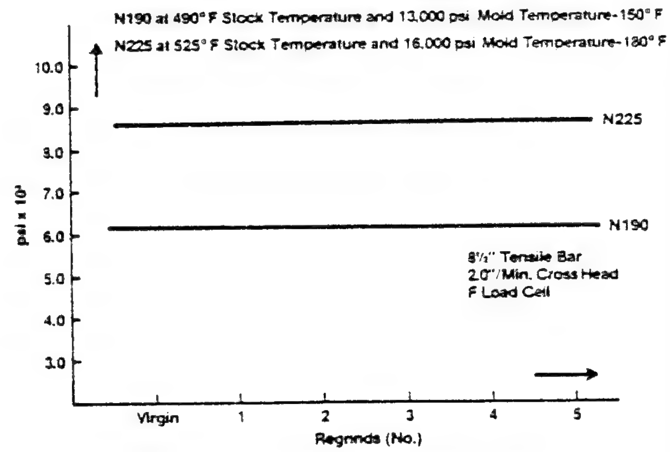


Figure 3

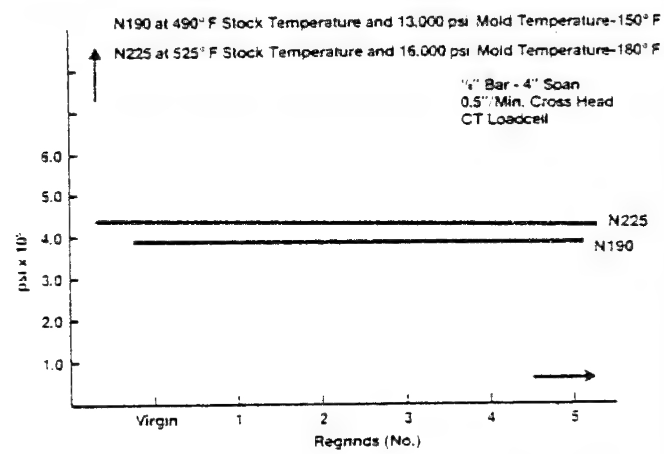
Tensile Strength vs. Regrind



Flexural modulus (Figure 4) show only about 2% reduction through 5 regrinds for both resins.

Figure 4

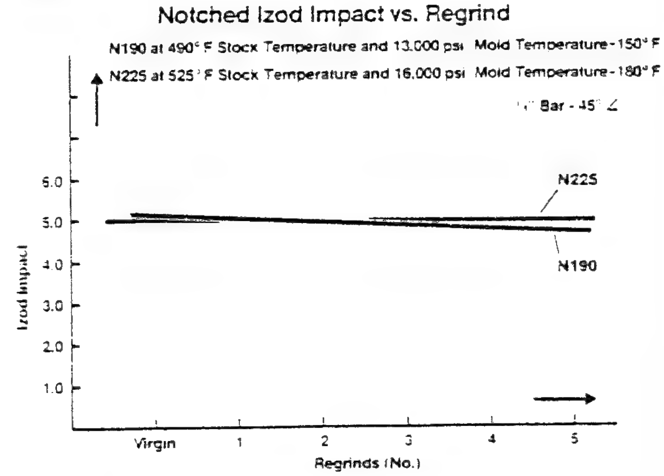
Flexural Modulus vs. Regrind



Notched Izod Impact, a primary indicator of a molded part's ability to withstand day to day abuse in the critical application areas, is shown against number of regrinds in Figure 5.

Figure 5

Notched Izod Impact vs. Regrind

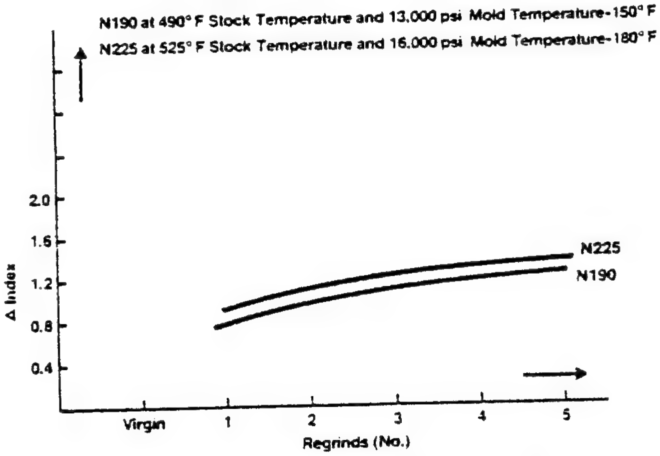


While N190 shows a decrease of approximately 8% for 5 regrinds, note that N225 shows no degradation over the entire range.

Yellowness index is plotted against number of regrinds in Figure 6.

Figure 6

Yellowness Index vs. Regrind



N190 shows a change in Index or approximately 1.2%. N225 shows a similar change of about 1.4%.

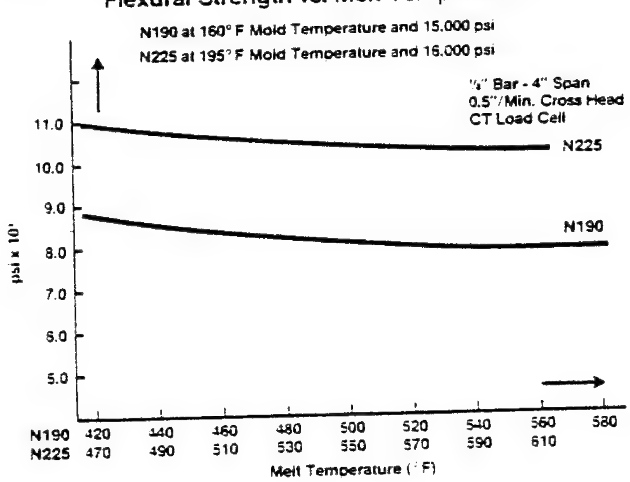
Physical Properties at Various Melt Temperatures

Figures 7 through 12 illustrate the impact of melt temperature on physical properties. Note that all melt temperature studies were conducted at constant mold temperature and injection pressure. For N190 this was 160 Degrees F. at 15,000 psi and 195 Degrees F. at 16,000 psi for N225.

Flexural strength, plotted in Figure 7, shows little change over the full melt temperature range. For N190, flexural strength decreases from 8800 psi at 420 Degrees F. to 7900 psi at 580 Degrees F., a change of approximately 11%. For N225, flexural strength decreases from 10,900 psi at 470 Degrees F. to 10,200 psi at 610 Degrees F., a decrease of approximately 7%.

Figure 7

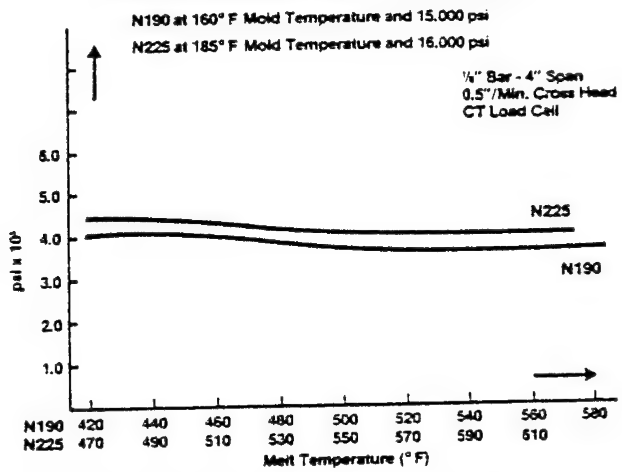
Flexural Strength vs. Melt Temperature



Flexural modulus, plotted in Figure 8, shows very similar decreases over the same temperature progressions. N190 decreases approximately 11%, from 410,000 psi at 420 Degrees F. to 370,000 psi at 580 Degrees F. N225 decreases about 10%, from 450,000 psi at 470 Degrees F. to 410,000 psi at 610 Degrees F.

Figure 8

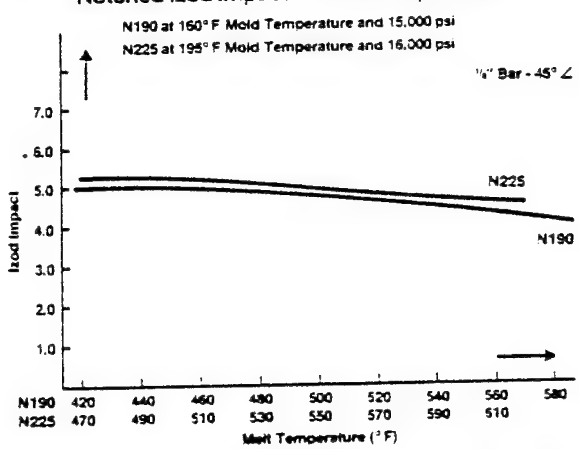
Flexural Modulus vs. Melt Temperature



Notched Izod Impact as illustrated in Figure 9 shows relatively little decline between temperatures of 420 Degrees F. and 530 Degrees F. for N225. Above these temperatures, the decline becomes more rapid.

Figure 9

Notched Izod Impact vs. Melt Temperature

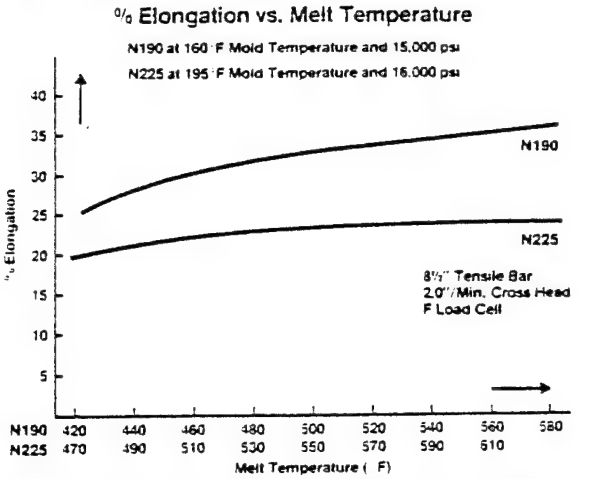


The implication is that "physical strength properties are inversely proportional to melt temperature, over the range of suitable melt temperatures for each resin." True, but the possible resulting conclusion that melt temperatures should therefore be kept to a minimum must be moderated by two other influences: 1) That knit line properties are directly proportional to melt temperature, and 2) That flow characteristics are directly proportional to melt temperature.

Therefore, the conclusion stated above might be restated as follows: "Melt temperatures should be kept as low as possible (within the suitable range) compatible with suitable knit line characteristics and flow capability that matches required mold flow distances."

Continuing with the discussion of properties versus melt temperature, review of Figure 10 will demonstrate that % elongation increases somewhat with melt temperature.

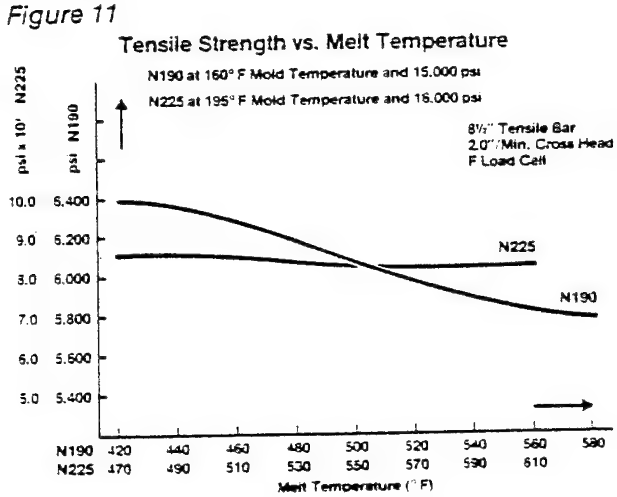
Figure 10



For N190, the elongation increases from 25% at 420 Degrees F. to approximately 35% at 580 Degrees F. For N225, the increase is more moderate, from 20% at 470 Degrees F. to approximately 24% at 610 Degrees F.

Figure 11 plots tensile strength versus melt temperature for both resins.

Figure 11

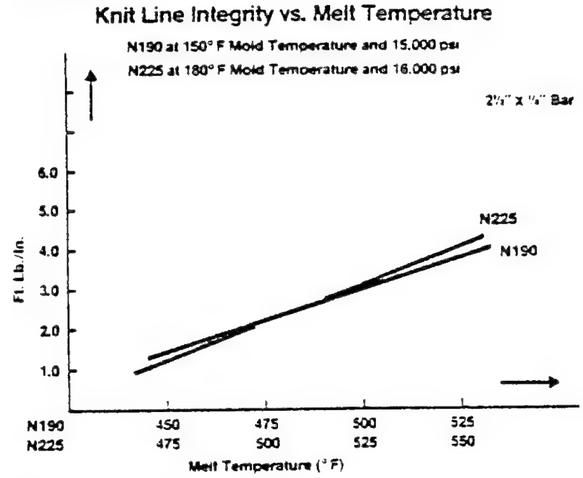


As shown, tensile strength is highest for the lower melt temperatures and decreases as melt temperature rises. Note that, while for N190 the change is approximately 10%, decreasing from 6400 psi at 420 Degrees F. to 5800 psi at 580 Degrees F; the change for N225 is much smaller. Less than 4% decrease is indicated for N225, decreasing from 8600 psi at 470 Degrees F. to 8300 psi at 610 Degrees F. This is, of course, to be expected, and conforms with the ratings of the two materials.

Knit Line Properties

Figure 12 plots knit line integrity in foot-pounds per inch versus melt temperature for N190 and N225 respectively.

Figure 12



Note that the strength of the knit line bond increases markedly over the melt temperature ranges shown. For N190, knit line strength is approximately 1.5 ft.-lb./in. at 450 Degrees F., whereas at 525 Degrees F., it has increased to 3.8 ft.-lb./in., an increase of more than 150%. For N225, the increase is even more pronounced, from 1.3 ft.-lb./in. at 475 Degrees F. to 4.2 ft.-lb./in. at 550 Degrees F., an increase of 225%.

The proportional increase in knit line strength continues only to a certain point, however. Beyond that critical melt temperature, knit line strength will decrease with further increases in temperature.

The actual point at which the curve reverses varies according to which resin is used and according to injection pressure and mold temperature. Generally speaking, it is wise to avoid processing temperatures about 580 Degrees F. for N190 and 610 Degrees F. for N225.

Note that for these plots of knit line integrity, mold temperature and injection pressure were held constant. For N190, the conditions were 150 Degrees F. mold temperature and 15,000 psi. For N225, they were 180 Degrees F. and 16,000 psi.

Physical Properties at Various Mold Temperatures

Figures 13 through 17 are plots of the physical properties of molded parts made from N190 under conditions of varying mold temperatures. Melt temperature and injection pressure were held constant at mid-range values; 490 Degrees F. and 15,000 psi respectively. For N225, melt temperature was 525°F. and injection pressure was 16,000 psi.

It is immediately obvious that mold temperature has a considerable lesser impact on physical properties than did melt temperature. One can further postulate, on extension of the data for both melt temperature and mold temperature, that melt temperature can be selected as the gross tuning parameter for a specific application, and mold temperature can be used to fine tune the finished part to the desired properties.

Reviewing Figure 13 shows that flexural strength is independent of mold temperature for the samples and temperatures tested. Further, while N190 shows a very slight degradation of flexural modulus over the range of mold temperatures from 100° F. to 175° F., N225 shows no impact at all over the range of 100° F. to 200° F.

Figure 13

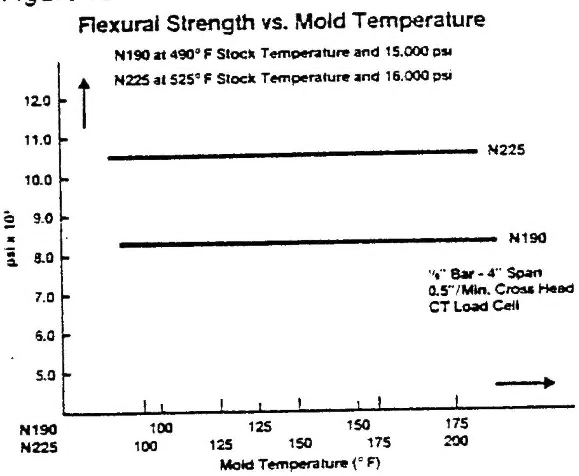
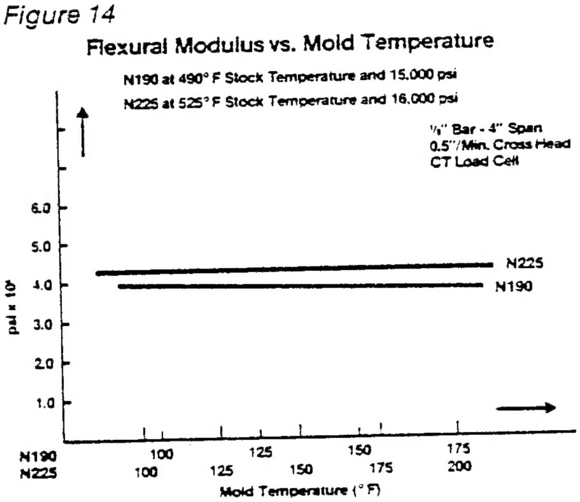
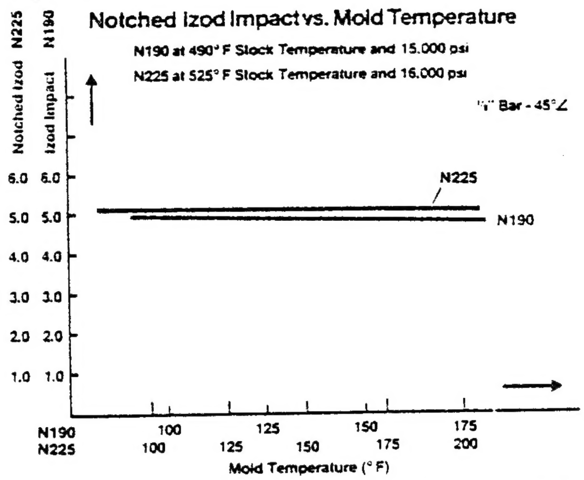


Figure 14



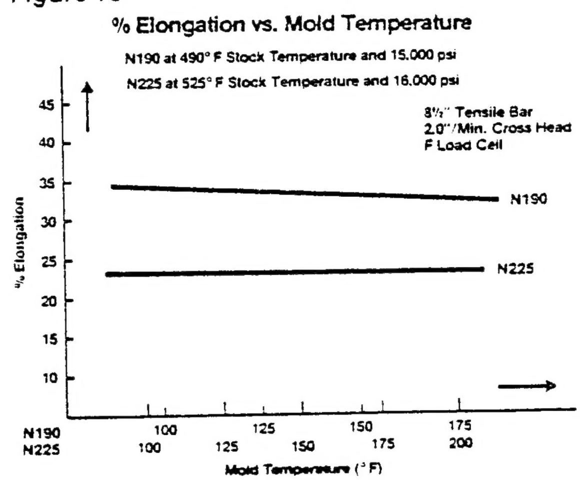
For both resins, Notched Izod Impact testing showed about 2% decrease in measured data over the mold temperature ranges.

Figure 15



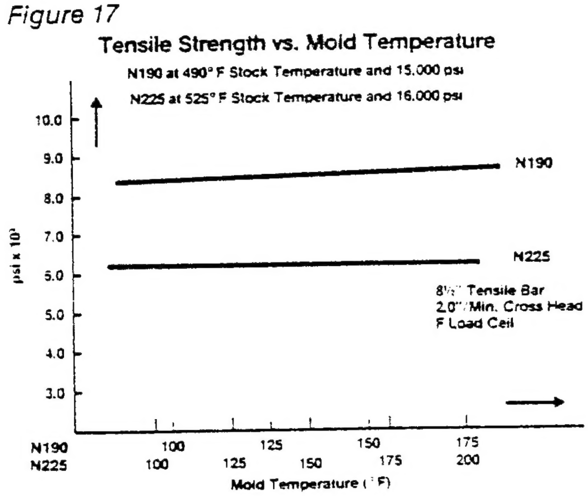
The N190 samples showed approximately a 2.5% *decrease* in elongation over the range of 100° F. to 175° F., while the N225 samples showed no change at all from 100° F. to 200° F.

Figure 16



For tensile strength, N190 samples showed *increased* strength over the range, from 8400 psi at 100° F. to 8600 psi at 200° F., a change of +2%.

Figure 17



Not shown in the figures is similar slightly positive impact on knit line strength as mold temperature is increased. This effect, while not quantized, is substantially more for N225 than for N190.

Again, the selection of mold temperature can be made after melt temperature is established, to provide optimal results for a particular melt temperature.

Effect of Melt Temperature on Flow Length
Figure 18 illustrates the effect of wall section on flow length for 4 different melt temperatures for N190.

Figure 18

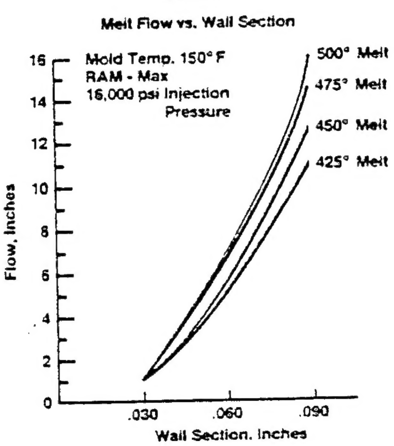
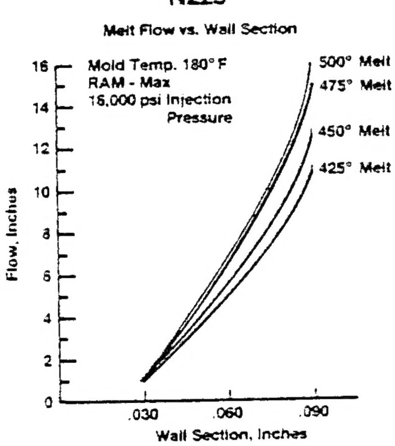


Figure 19 shows the same information for N225.

Figure 19



Both sets of curves provide the temperature flow relationship for three different wall sections—.030", .060", and .090".

It is obvious that for a given wall section, flow is directly proportional to both injection pressure and melt temperature which these two figures bear out. The charts represent, for fixed mold temperature, the maximum flow that a molder may expect for the mid-range values of melt temperature and injection pressure.

Conversely, one may use flow curves to establish minimum wall section values when flow length is known. For example, using N225 resin, a part with a 9 inch flow length from its gate would require a melt temperature of 500° F. if the wall section is .090".

Other Processing Information for Molding with Noryl N190 and N225
Information presented in this section of the paper is to aid the molder who seeks a single reference document to assist him in molding these two unique resins in his existing machines and molds.

The Machine
The reciprocating screw machine has been shown to be the most effective for utilization of Noryl resins. General purpose screws with L/D ratios up to 24/1 and compression ratios of 2/1 to 3/1 are satisfactory. Vinyl screws or tips are not recommended.

Molding temperatures will be generally higher for Noryl resins other thermoplastics. Ranges of about 420° F. to about 580° F. are suitable for N190 resins, 470° F. to 610° F. for N225 resins.

The Mold
Molds used for other engineering thermoplastics can be used with Noryl N190 and N225 resins, if certain minor modifications are made. Gate sizes should be increased to as large as is practical. Similarly, vents should be made large, and tapers should be as generous as possible. Molds should be well cored with water lines to insure uniform mold temperatures.

Heated molds are definitely recommended, since mold temperature can be used to improve molded part characteristics. Temperatures of 150° F. to 200° F. are recommended.

Resin Compatibility
Parts molded of Noryl resins may be operated with immunity in most environments. However, certain oils, greases, solvents and sealing materials are not compatible with Noryl N190 and N225 resins.

A list of those materials which would have deleterious effects on Noryl parts is available from the Noryl Products Department of General Electric.

Post Molding Treatments
Parts made of Noryl N190 and N225 resins can be machined, drilled, turned, bored, milled, tapped, reamed and annealed.

They can also be painted with alkyd, acrylic and eopxy with no special pre-paint surface preparation. Similarly, woodgraining finishes may be applied to Noryl parts.

Parts may be hot stamped, electroplated, printed, silk screened, vacuum metalized, velvetized and suede-coated.

In short, Noryl resin parts can be finished with almost any technique currently used on plastic or metal parts.

Summary
The needs of the automotive, water handling, business machine, TV and electronics, and appliance markets for key molded plastic parts to meet unusually high performance requirements resulted in the development of the N190 and N225 engineering thermoplastic resins. These resins offer much of the flame retardance, strength, hydrolytic stability, and heat resistance required of the above industries.

INITIATION FEE MUST BE ATTACHED FOR PROCESSING

SOCIETY OF PLASTICS ENGINEERS, INC.

656 West Putnam Avenue
Greenwich, Connecticut 06830

MEMBERSHIP APPLICATION

PLEASE PRINT OR TYPE

J

FOR EXECUTIVE OFFICE USE ONLY
I.D. #.................... Grade.........
Section.............. Division........
Job Class.................................
Date Elected..........................

☐ I wish to become a member of
☐ I wish reclassification within
☐ I wish reinstatement in (full year's dues—no initiation fee)

the Society of Plastics Engineers. (Check below the membership grade for which you feel qualified. See reverse side.)

☐ Student Memb. ☐ Affiliate Memb. ☐ Member ☐ Senior Memb. (Reclass. Only)

INITIATION FEE: $10 (Student, none)
FEE IS SEPARATE FROM DUES

ANNUAL DUES: Student—$8 **U.S.A.**—$35 **Canadian & Foreign**—$35
(July 1-Dec. 31, Full Dues; Jan. 1-March 31, Half Dues; Apr. 1-June 30, Initiation Fee Only)

I wish to join the ______ Section, and Primary Division No ______ (see rev. side)

My name: ______
(First) (Middle) (Last) (Citizen of) (Date of Birth)

Fill in **both** addresses and **CHECK THE ONE TO WHICH YOUR MAIL SHOULD BE ADDRESSED:**

☐ **COMPANY** (spell out name): ______ **DIVISION:** ______

Position ______ (Complete JOB FUNCTION box on reverse side)

Address ______ City ______ State (Prov.) ______ Zip ______

☐ **HOME:** Address ______ City ______ State (Prov.) ______ Zip ______

REFERENCES The By-Laws require the names of three references who are familiar with your work. One of them should be a member of the Society. Assistance in providing member-references, when needed, will be given on request. Signatures are not necessary.

1. (Memb - Sponsor) ______ Address ______
2. ______ Address ______
3. ______ Address ______

STATEMENT OF COLLEGE WORK

Years Attended		Institution	Major	Degree	Experience Credits (See reverse side)
From	To				
				SUB-TOTAL	

RECORD OF QUALIFYING EXPERIENCE IN PLASTICS

Dates				Give your title, name and location of employer. List in chronological order. Describe duties fully and state any important engineering work you have done in each position. If space is not sufficient, use a separate sheet.	Time in years (a)	% in Plastics (b)	Qualifying experience (a x b)
From		To					
Mo.	Yr.	Mo.	Yr.		yrs. mo.		yrs. mo.

I certify that the statements made in this application are correct. I agree, if elected, to be governed by the Constitution and By-Laws of the Society, and to promote the objectives of the Society.

SUB-TOTAL ______

Total education and experience credits. ______

INITIATION FEE MUST BE ATTACHED FOR PROCESSING.

NATIONAL CREDENTIALS COMMITTEE APPROVAL ONLY	Approved Grade
(S) Date	
(S) Date	

Signature in ink. Date

Please complete other side of application ►

JOB FUNCTION

What is the primary end product manufactured, or service performed, at your company location?

....

....

Check your primary job function
(check one only)

("IM" means "Including Management")

A....Production or Manufacturing Engineering (IM)
B....Design or Design Engineering (IM)
C....Purchasing (IM)
D....Sales or Marketing (IM)
E....Research or Development Engineering (IM)
F....General or Corporate Management
G....Other (Specify) ....
....

DIVISIONS

Indicate the Division(s) of your choice. You must mark "1" for your Primary choice; check others (Secondary Divisions cost $3 each). Indicate your Primary choice in space provided on application (over).

21....Color and Appearance
22....Extrusion
23....Injection and Rotational Molding
24....Electrical and Electronics
25....Thermoforming
26....Engineering Properties and Structure
27....Vinyl Plastics
28....Thermosetting Molding
29....Thermoplastics Materials and Foams (Nonvinyl)
30....Blow Molding
31....Plastics in Automotive
32....Plastics in Buildings
33....Plastics Analysis
34....Decorating of Plastics
35....Moldmaking and Mold Design

EXPERIENCE CREDITS

Grade of Membership...

Membership grades are based on experience credits which are earned as follows:

1. **Experience credits earned for education.**

Doctorate in science or engineering	6 credits
Masters in science or engineering	5 credits
Bachelors in science or engineering	4 credits
Any degree other than the above	2 credits
Associate or Adjunct in Plastics	2 credits
Associate or Adjunct (awarded by Community College or equivalent for two year course of studies, without specializing in plastics).	1 credit

   Maximum credits allowable for education shall be six (6). Use highest degree credits only. When filling in the "Statement of College Work" on the reverse side, place the corresponding number of credits earned in the right-hand column.

2. **Experience credits** are determined by the proportion of time involved in actual technical and engineering duties in plastics **for each position held.** For instance, if only three of the five years you worked for the XYZ Co. comprised technical or engineering duties, then three (3) years (60% of 5 yrs.) would constitute the "Qualifying Experience" you would enter in years and months in the right-hand column under "Record of Qualifying Experience in Plastics."
   Please detail carefully the engineering skill required for each position to help the Credentials Committee judge experience as "qualifying."

When you have determined the number of credits which you believe you have earned, consult the following member grade requirements. Indicate on the reverse side (above "Annual Dues") the grade of membership for which you believe you are qualified.

GRADE	REQUIREMENTS
Senior Member	Minimum of twelve (12) experience credits and current continuous membership in the Society for a minimum of two (2) years.
Member	Minimum of six (6) experience credits
Affiliate Member	Less than six (6) experience credits
Student Member	Regularly enrolled full time student in a course of study in plastics.

SPE SECTIONS

AKRON
ARIZONA (incl W N.M.)
ARK LA TEX (SW Ark., NW La., NE Tex.)

BALTIMORE WASHINGTON (incl N Va., S Del.)
BARTLESVILLE TULSA
BINGHAMTON-SCRANTON (incl NE Pa.)
BRITISH COLUMBIA
BUFFALO

CENTRAL FLORIDA
CENTRAL INDIANA
CENTRAL NEW YORK
CENTRAL OHIO
CHICAGO
CLEVELAND
COLUMBIA (Ore., SW Wa.)
CONNECTICUT (S half)

DELAWARE VALLEY (Cent. N.J.)
DETROIT

EAST CENTRAL ILLINOIS
EASTERN NEW ENGLAND (Me., SE N.H., Boston)

FLORIDA (S half)
FRANCE

GOLDEN GATE (N half Ca.)
GULF SOUTH CENTRAL (La.)

HUDSON MOHAWK W Vt., W Mass., E N.Y.)

ISRAEL

ITALY

JAPAN

KANSAS CITY
KENTUCKIANA (incl SE Ind.)

MEXICO CITY
MIAMI VALLEY (SW Ohio, N Ky., E Ind.)
MID-MICHIGAN (incl peninsula)
MID-HUDSON (below Hudson-Mohawk)
MID-SOUTH (W Tenn., C and E Ark., N Miss.)
MILWAUKEE
MONTERREY (N Mexico)

NEW YORK
NEWARK

NORTH SEA DELTA (Belgium, Nether.; Lux.)
NORTH TEXAS (Dallas area)
NORTHERN INDIANA
NORTHWEST PENN.

OHIO FIRELANDS (Sandusky area E and S)
OMAHA
ONTARIO

PACIFIC NORTHWEST (Wa.)
PALISADES (N.J. opp N.Y.)
PIEDMONT COASTAL (E. N.C. & S.E. Va.)
PHILADELPHIA (incl S N.J., N Del.)
PIONEER VALLEY (N.H., E Central Mass.)
PITTSBURGH

QUEBEC

REPUBLIC OF CHINA (Taiwan)
ROCHESTER
ROCK VALLEY (N Ill., S Wisc., E Iowa)
ROCKY MOUNTAIN (Utah, Col., S Wy.)

SCANDINAVIAN

ST. LOUIS (W Ill., C and E Mo., E Ark., NW Miss.)
SOUTH BEND Extreme North Cent. Ind.
SOUTH TEXAS
SE NEW ENGLAND (E CT., R.I., Cape Cod)
SOUTHEASTERN OHIO
SOUTHERN (S and E Miss., Ala., Ga., N Fla., SE S.C.)
SOUTHERN CALIFORNIA
SUSQUEHANNA (C Pa.)
SWITZERLAND
TENNESSEE VALLEY (C Tenn.)
TENN. VA. HOLSTON VALLEY
TOLEDO
TRI STATE (SE ILL., SW Ind., E Ky.)
UPPER MIDWEST (N and S. Dak., Minn., N Iowa, NW Wisc.)
VIRGINIA-CAROLINAS (S half Va., N.C., NE S.C.)
WESTERN MICHIGAN
WESTERN NEW ENGLAND (E Vt., W and C Mass., N Conn.)
WICHITA
NON SECTION (Unassigned areas)